An agent-based model for the management of the emergency department during the COVID-19 Pandemic.

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My short biography

- ✓ My name is Ramona Galeano.
- ✓ I am pursuing my Ph.D. in Computer Science at the Autonomous University of Barcelona, Spain.
- ✓ I am a Master in Software Engineering at the National University of Asuncion, Paraguay.
- ✓ Master in Java programming at the University of Alcala in Madrid, Spain.
- ✓ I am a teaching assistant and research professor at the National University of Asunción, Paraguay.

Agent-based model

Propose **an agent-based model** that allows the simulator's functionality **to be extended emergency department** when there are exceptional situations such **as pandemics**.

We have a simulator

- The design allows the simulation of **spread of infections by contact (MRSA)** and similar.
- **Some requirements must be added** to simulate a pandemic situation.

USING SIMULATION

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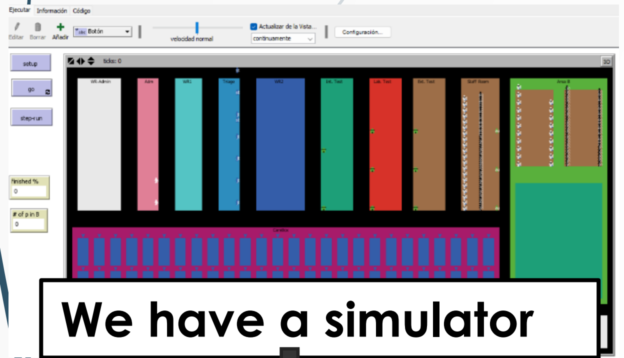

We have a simulator

It should be adapted to another environment

IPS INGAVI HOSPITAL

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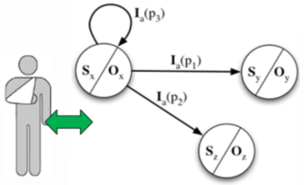
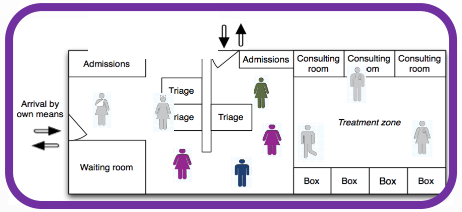
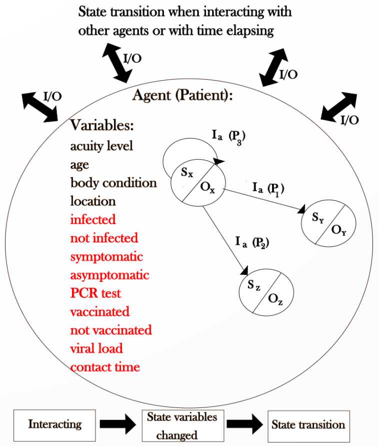






- **Rooms**
- **Laboratories (PCR)**
- **Separate infected from not infected**
- **Set of synthetic input data has been prepared**

Introduction

- Very **complex systems**.
- Improving these services can be **considered a great challenge** for any hospital administrator.
- The administration of emergency department is an area that **needs support from computer techniques** that help in the planning of a good distribution of human and material resources.

Covid-19 at the Social Security Institute (IPS) Ingavi Hospital.

IPS offers services to more than **2,000 insured persons per day**, with approximately **1,500,000 insured people**.

IPS is one of the **reference** modern **high-complexity hospitals for the care of patients with COVID-19**.

From March 2020 to September 2021, IPS **treated approximately 15,000** COVID-19 patients, of whom **1,500 died** despite medical efforts.

Covid-19 at the Social Security Institute (IPS) Ingavi Hospital.

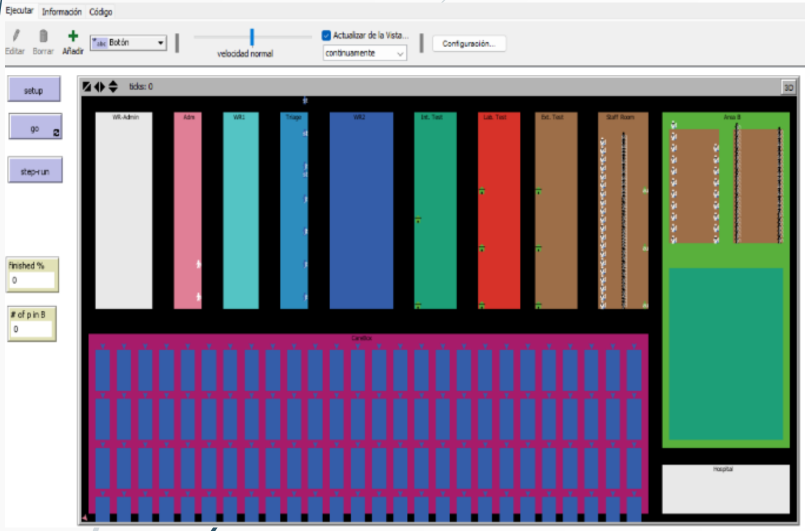
IPS has 246 beds for patient in hospital and 44 intensive care beds for the emergency department, **showing an increase of 97 and 16 beds**, respectively, from March to June 2021.

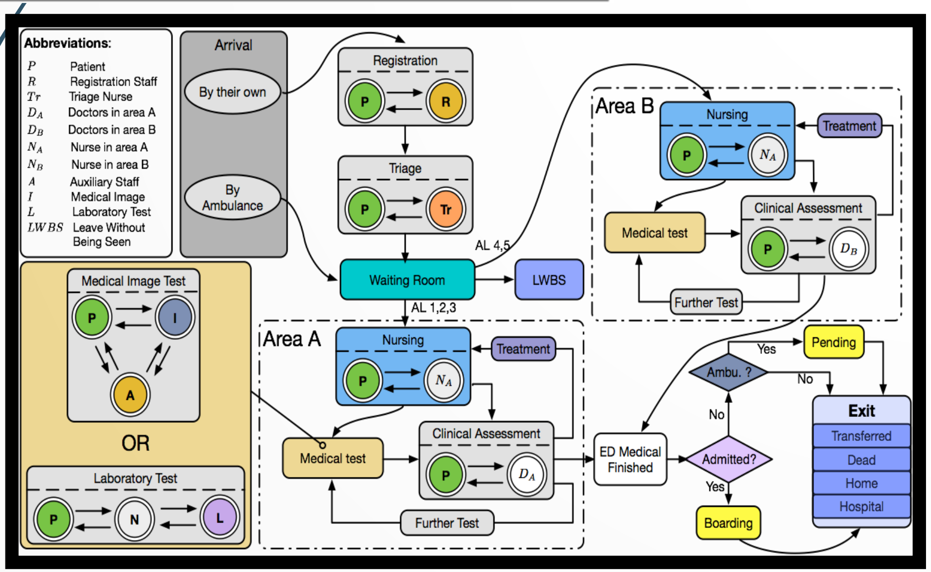
The staff of professionals was increased **with the incorporation of 126 doctors, more than 300 nurses, and 220 hospital staff** to respond to patients with COVID-19, with 30 armchairs, **attending up to 180 patients per day**.

Simulation in the emergency department

- **The simulation tool solves many problems** that cannot be addressed using the existing system for cost, time, or danger reasons.
- Simulation **provides a safer methodology for testing new techniques** without endangering people.
- It helps achieve a **more efficient and optimized patient care** system.
- It helps **make better use of resources**
- It is used as a **support** for a DSS.

Specifications of the current simulator:





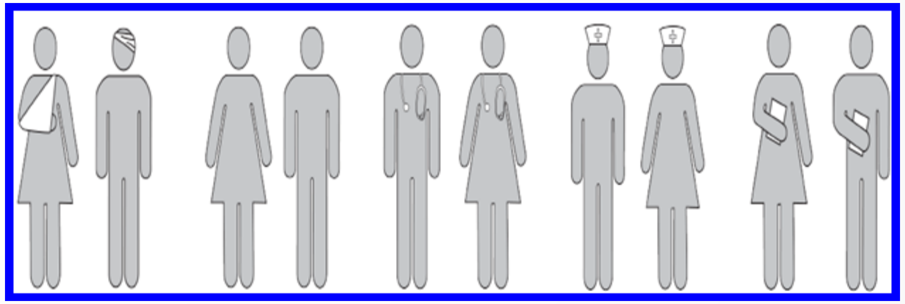
- The simulator with a specific model is **designed for emergency department for a Spanish Hospital**.
- The simulator with a design allows the similar **spread of infections by contact (MRSA)** and spread.
- The pandemic has arisen, and **some requirements must be added**.

Model

The model and the simulator had **to be adapted to another environment ¨Hospital IPS Ingavi¨**, and variables had to be included for the patients **to analyze the infection spreads within the service**.

A. Active agents.

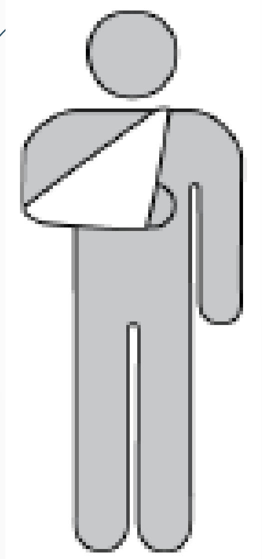
A) Active agents.
Patient
Admissions staff
Doctor
Triage nurse
Laboratory staff
Nurse



Patient model

- Necessary extensions on the current simulator:

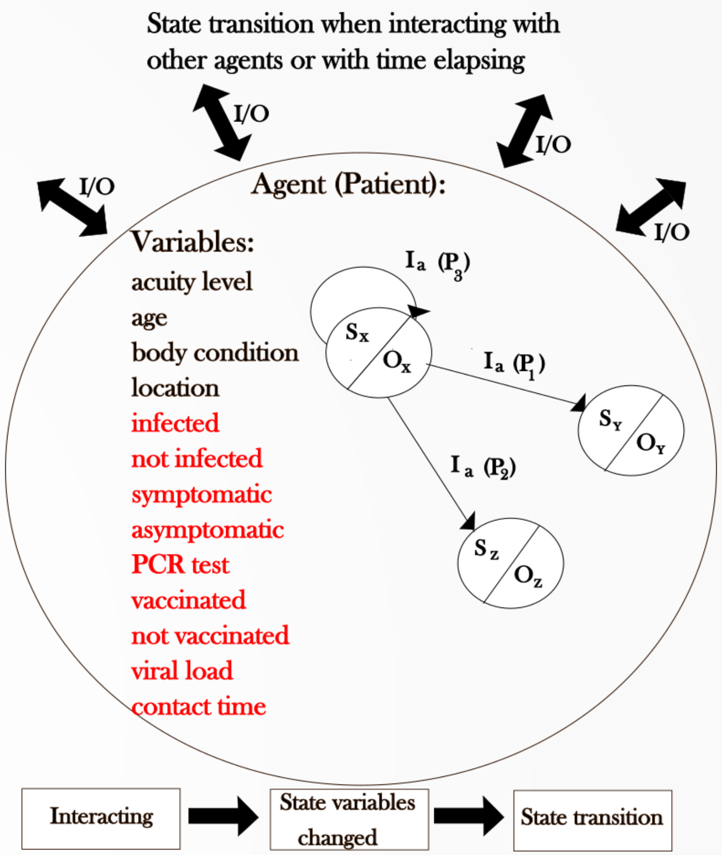
  The patient does not have a variable that identifies that:

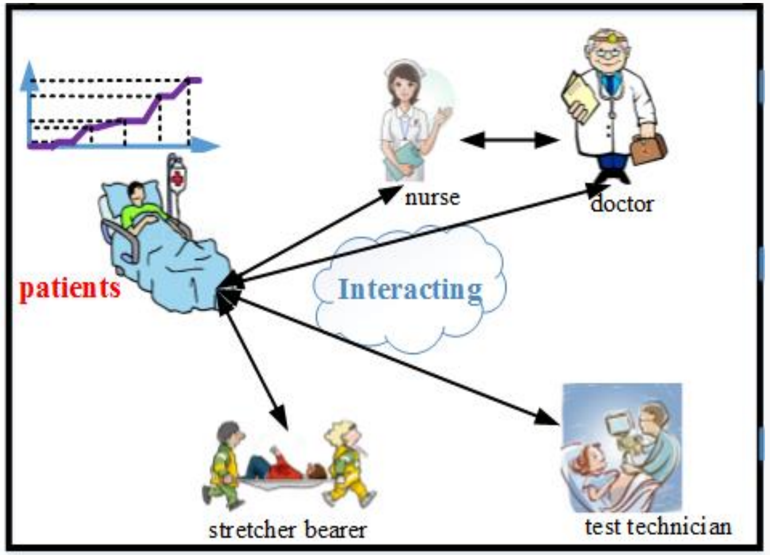


Infected

Not infected

Patient





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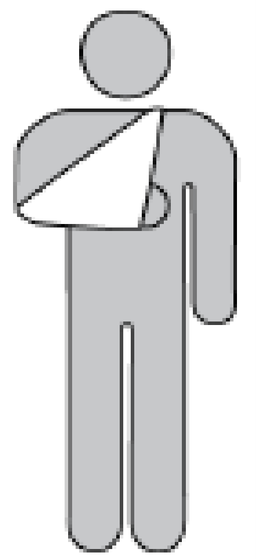
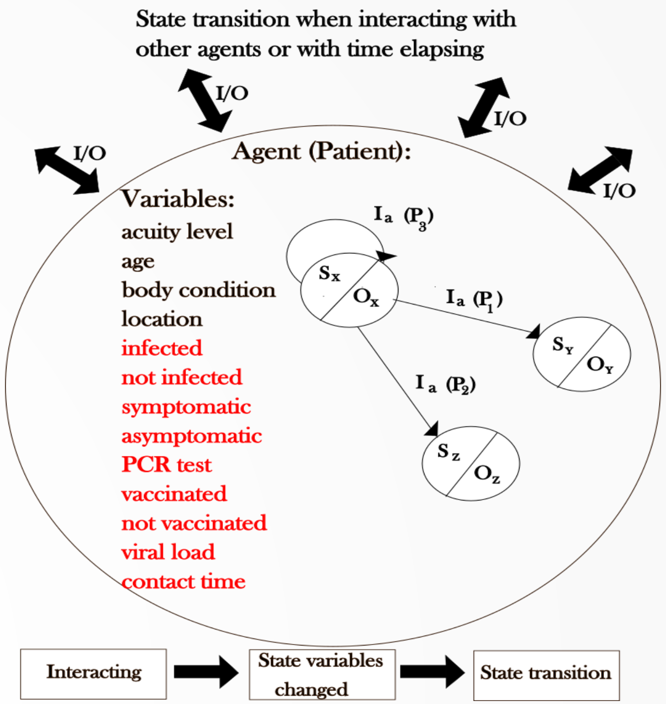


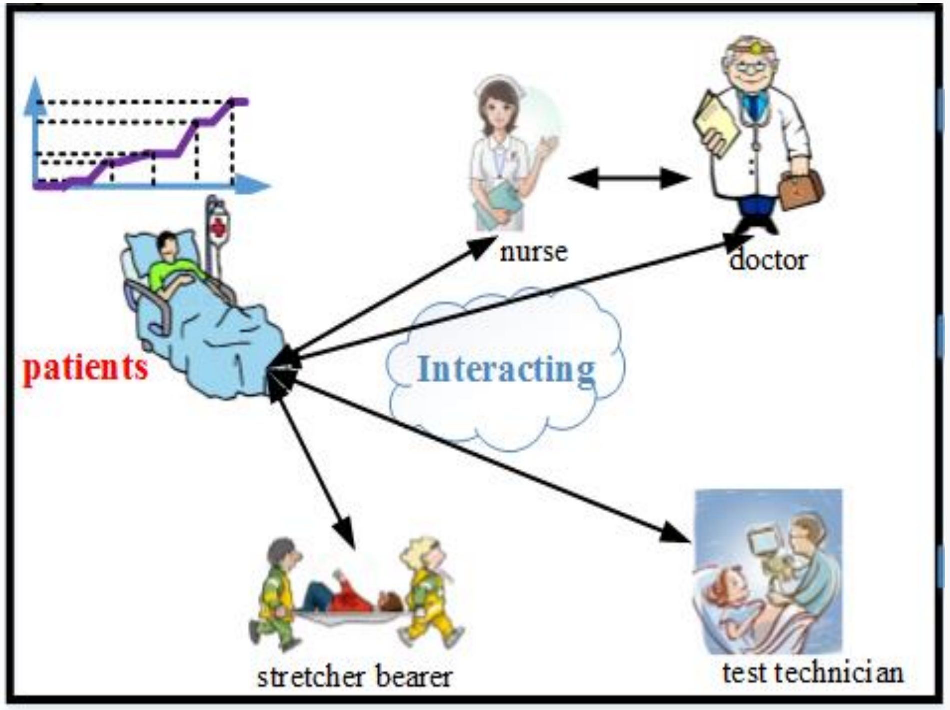
Patient

Symptoms

Asymptomatic

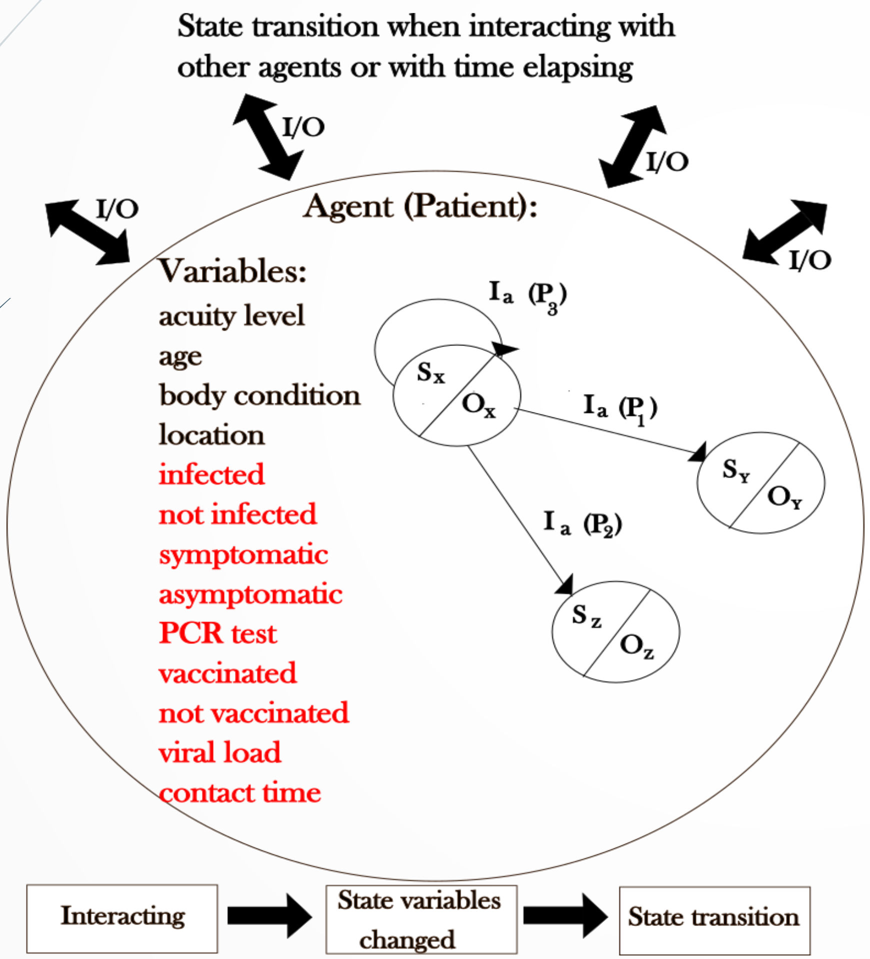
PCR test

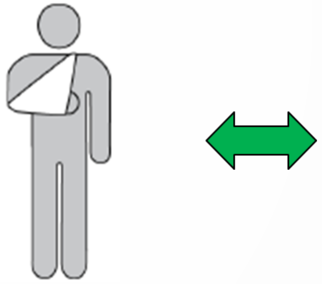


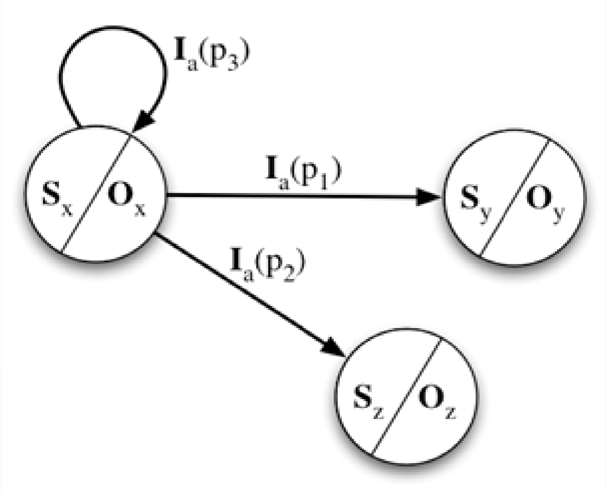


Model

State variables: from the patient agent

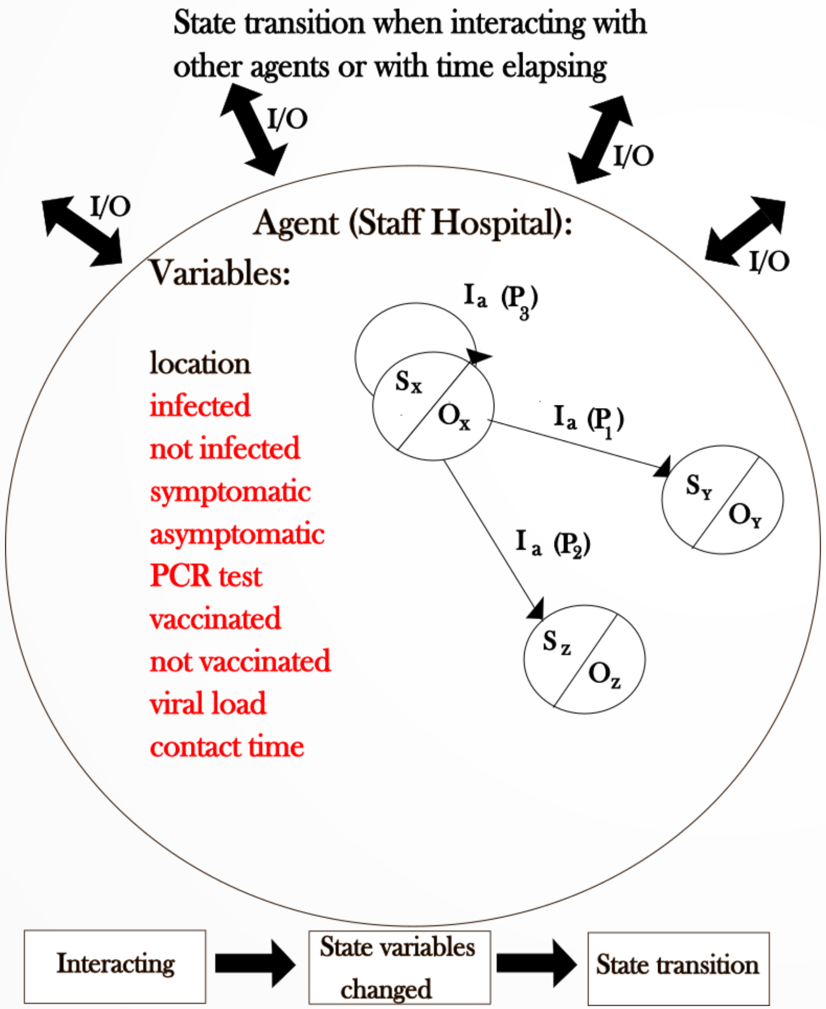


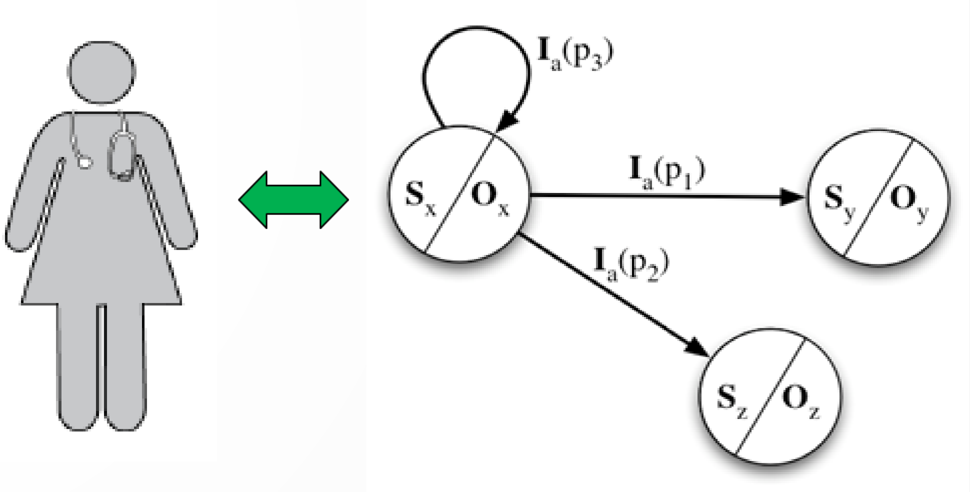




Model

State variables: from the staff hospital (doctor, nurse, admissions staff, triage nurse, laboratory staff) agent





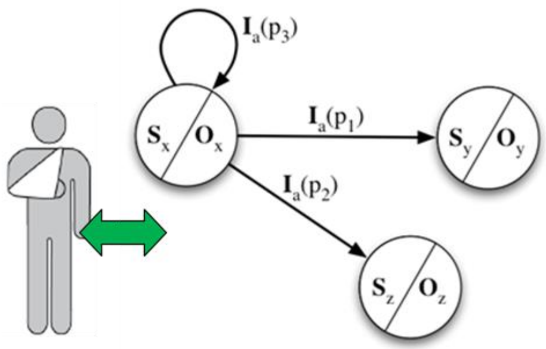
Model

P’1(%), P’2(%), P1(%), P2(%), P3(%) and P4(%) :
Represent the probability of the next state separately.

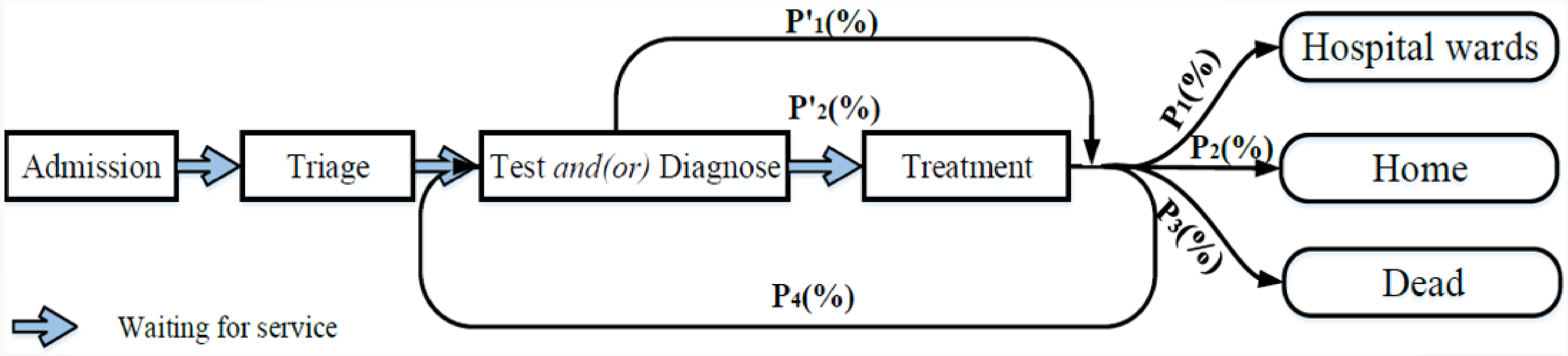
$$P_i = f(\mathrm{LoSC},\ \mathrm{age},\ \mathrm{level}),\ \sum_{i=1}^{4} P_i = 100\%$$

$$P'_i = f'(\mathrm{ToT},\ \mathrm{age},\ \mathrm{level}),\ \sum_{i=1}^{2} P'_i = 100\%$$

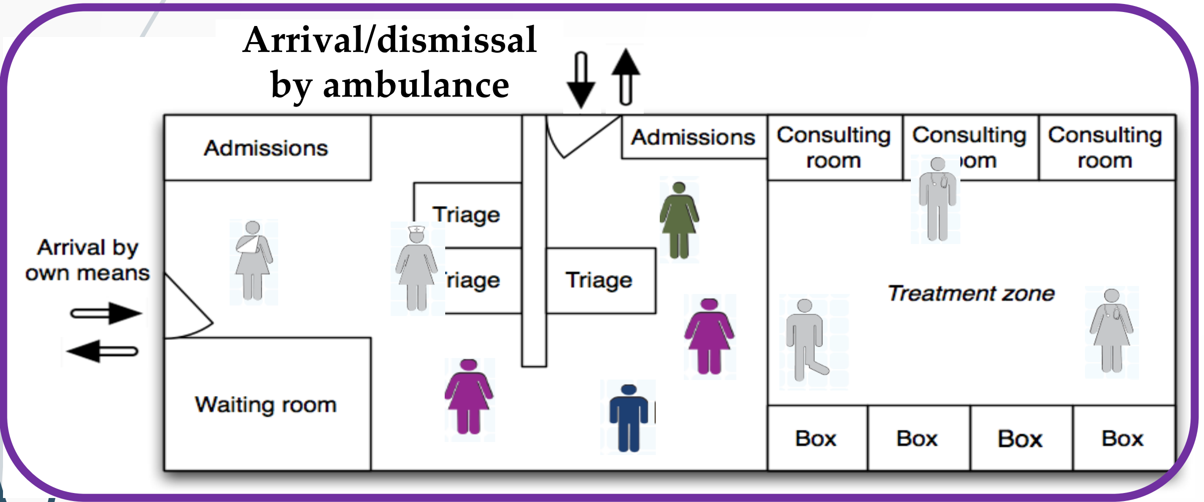
- **“LoSC”** is the patient’s length of stay in the carebox.
- **“Age”** is the age of the patient, which has big influence to the state transfer.
- **“Level”** is the acuity level of the patient.
- **ToT** is the type of test and (or) diagnosis.



Current state / Output	Input	Probability	Next state / Output
....	....	....	....
S_x / O_x	I_a (p_1)	p_1	S_y / O_y
S_x / O_x	I_a (p_2)	p_2	S_z / O_z
S_x / O_x	I_a (p_3)	p_3	S_x / O_x
....	....	....	....



Model



Rooms

Laboratories (PCR)

Separate infected from not infected

Input parameters

- ✓ Quantitative representation of the simulated emergency department.

- ✓ Staff Adaptation:

➨ Junior: inexperienced staff extra

➨ Senior: Staff with experience in the emergency department.

Staff	Quantity
Junior Admissions Staff	3
Senior Admissions Staff	3
Junior triage nurse	5
Senior Triage Nurse	5
Junior nurse area A	5
Senior nurse area A	5
Junior nurse area B	5
Senior nurse area B	5
Junior external laboratory	3
Senior internal laboratory	3
Junior doctor area A	10
Senior doctor area A	10
Junior doctor area B	10
Senior doctor area B	10

Input parameters

✓ Staff Adaptation:

- Junior: inexperienced staff extra
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Junior Admissions Staff	3
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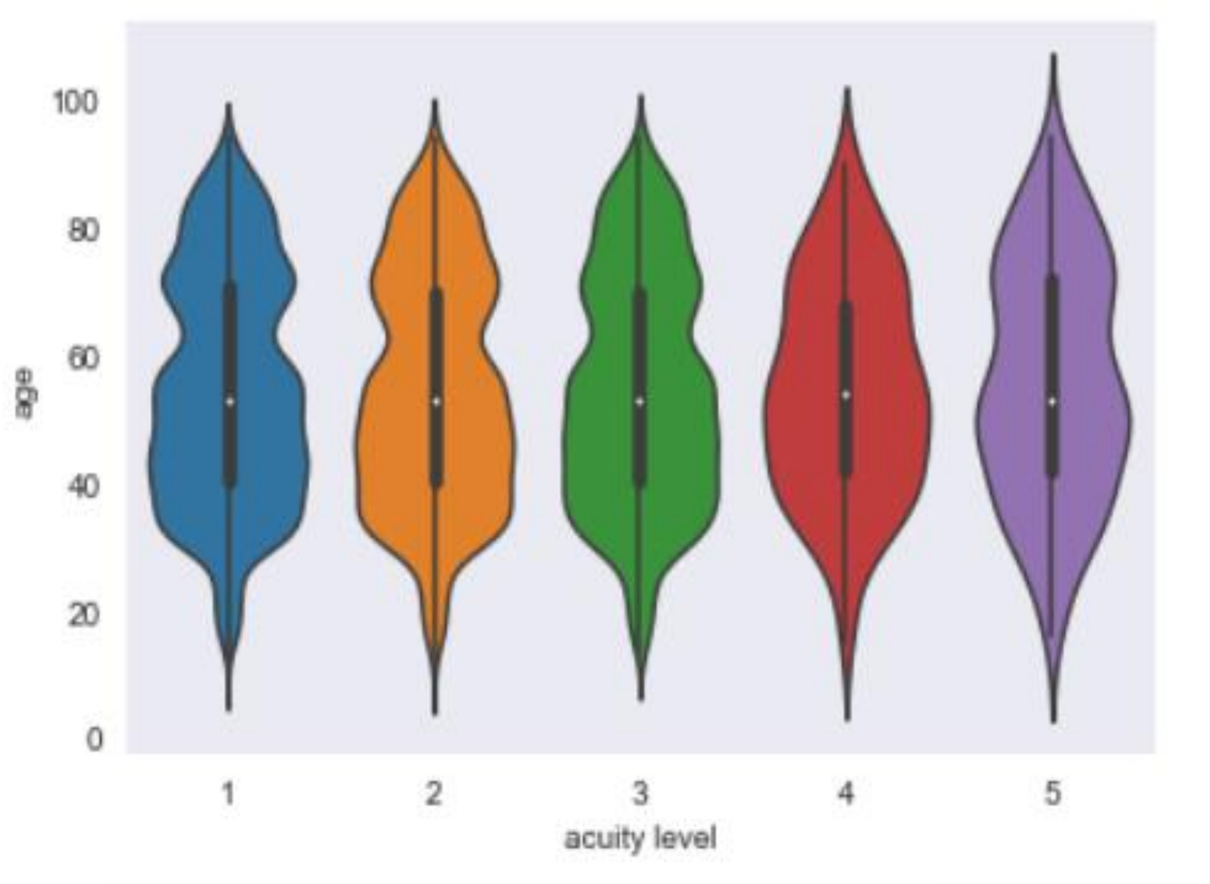
Junior triage nurse	5
Senior Triage Nurse	5
Junior nurse area A	5
Senior nurse area A	5
Junior nurse area B	5
Senior nurse area B	5
Junior external laboratory	3
Senior internal laboratory	3
Junior doctor area A	10
Senior doctor area A	10
Junior doctor area B	10
Senior doctor area B	10

Area A is the most critical patient.

Area B is the less critical patient.

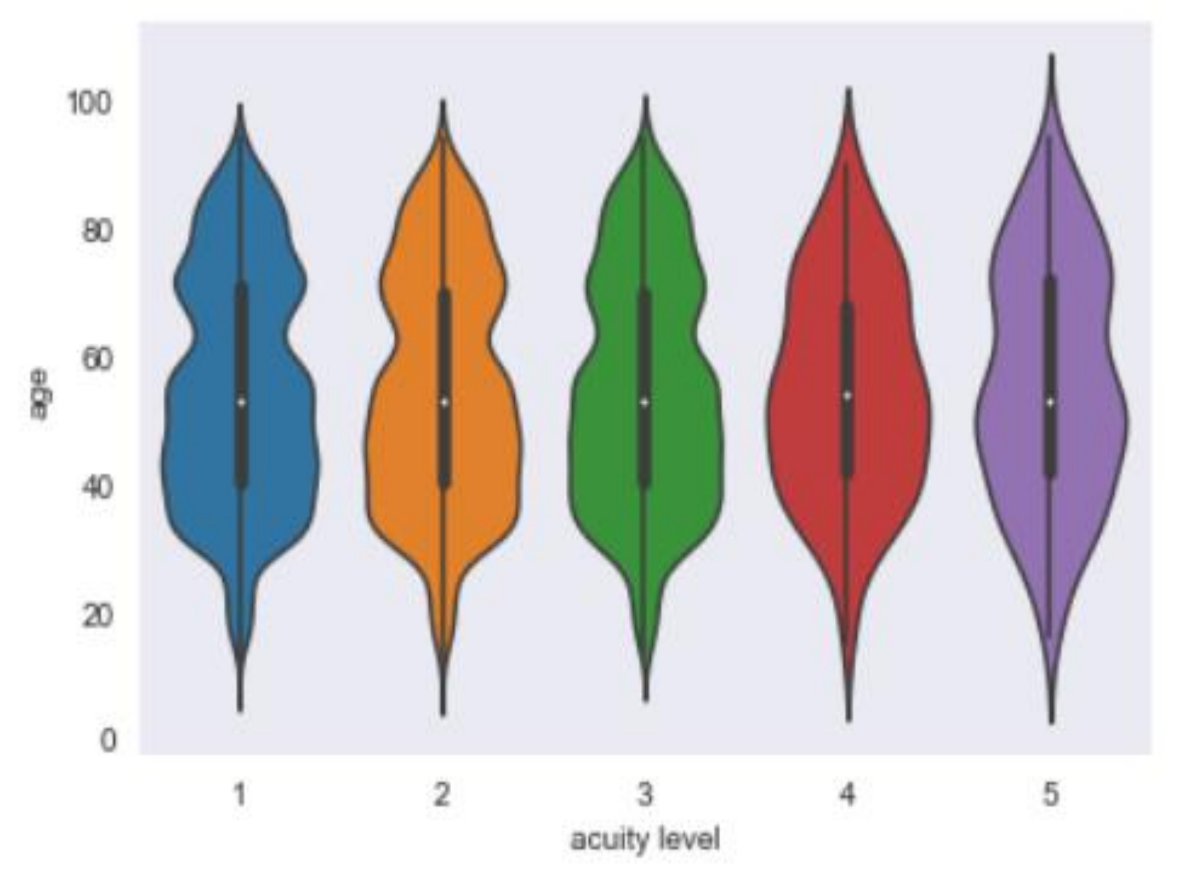
Characterization of patients entering the hospital

- The general distribution of arrival acuity level and the overall age distribution of simulated patients is in the figure.



Characterization of patients entering the hospital

- The general distribution of arrival acuity level and the overall age distribution of simulated patients is in the figure.
- Patients between the ages of 40 and 75 are the ones that go the most to the hospital.



Most critical

Less critical

Characterization of patients entering the hospital

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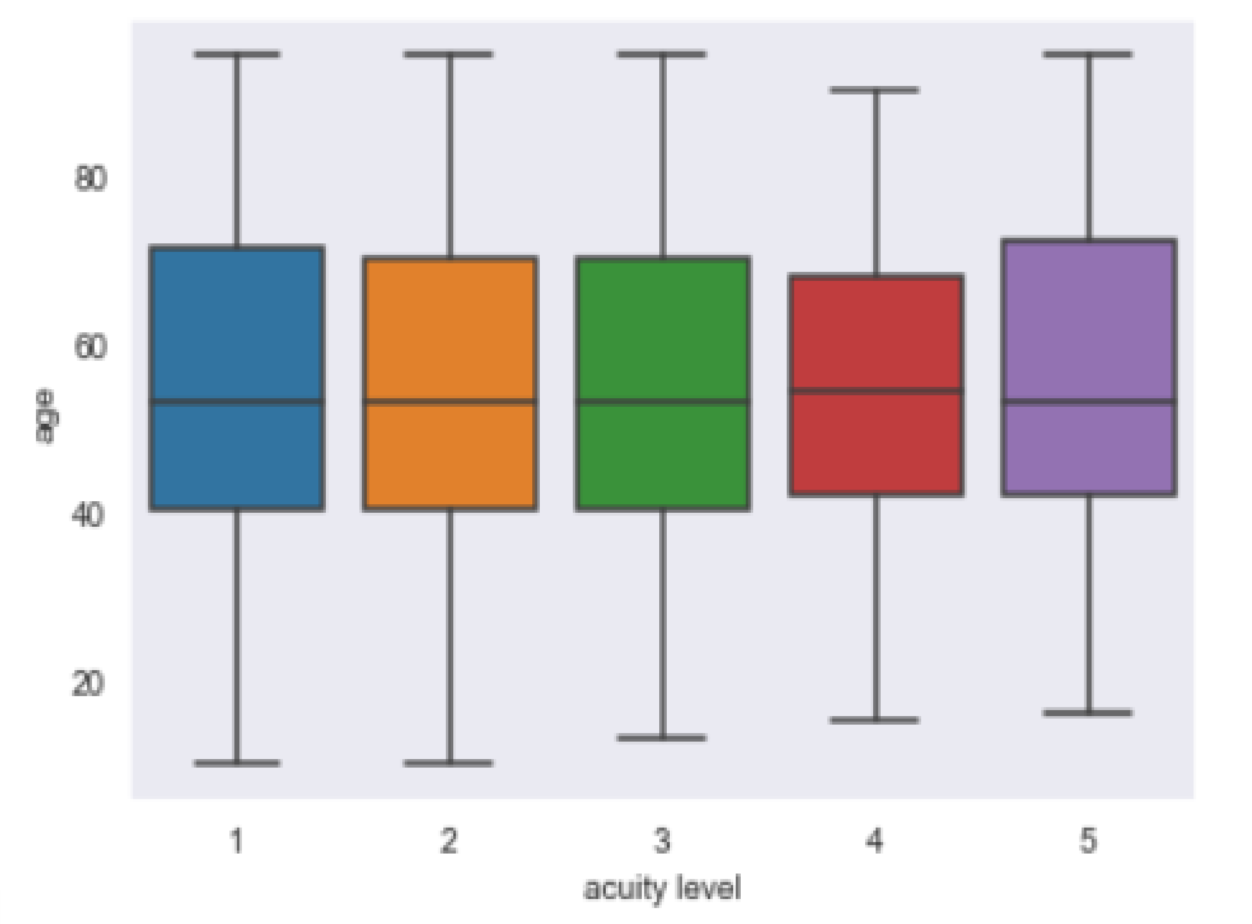

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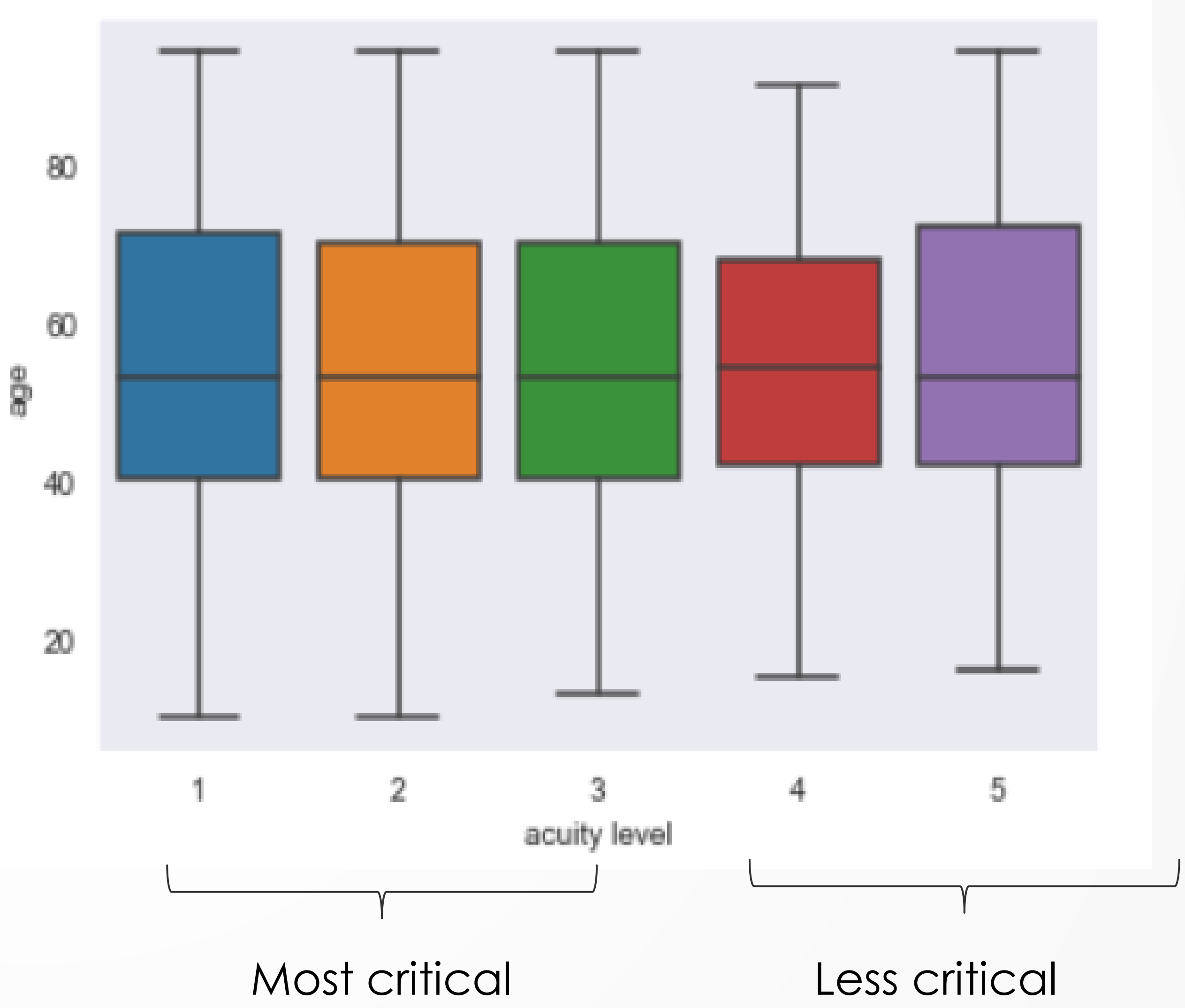
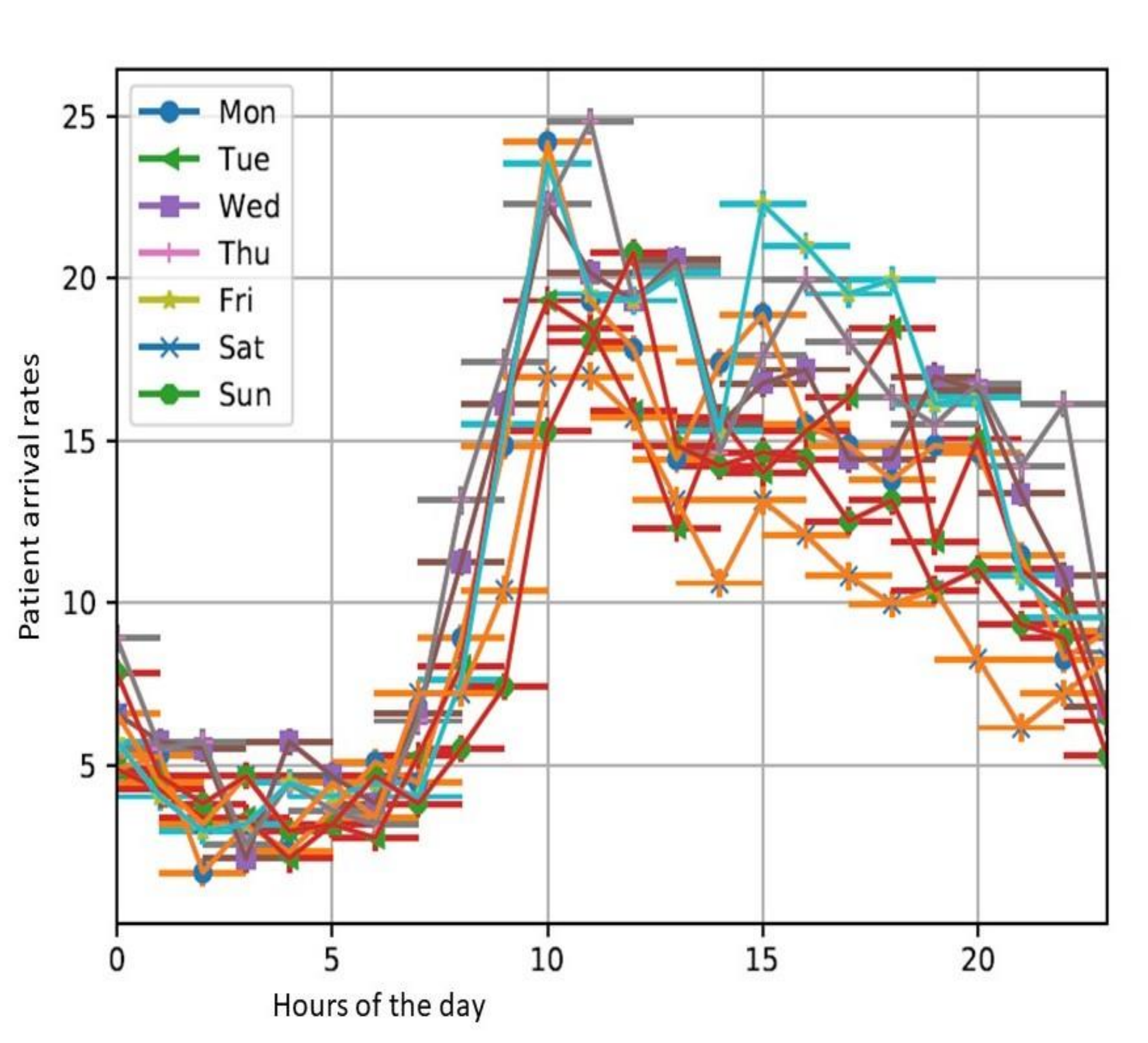


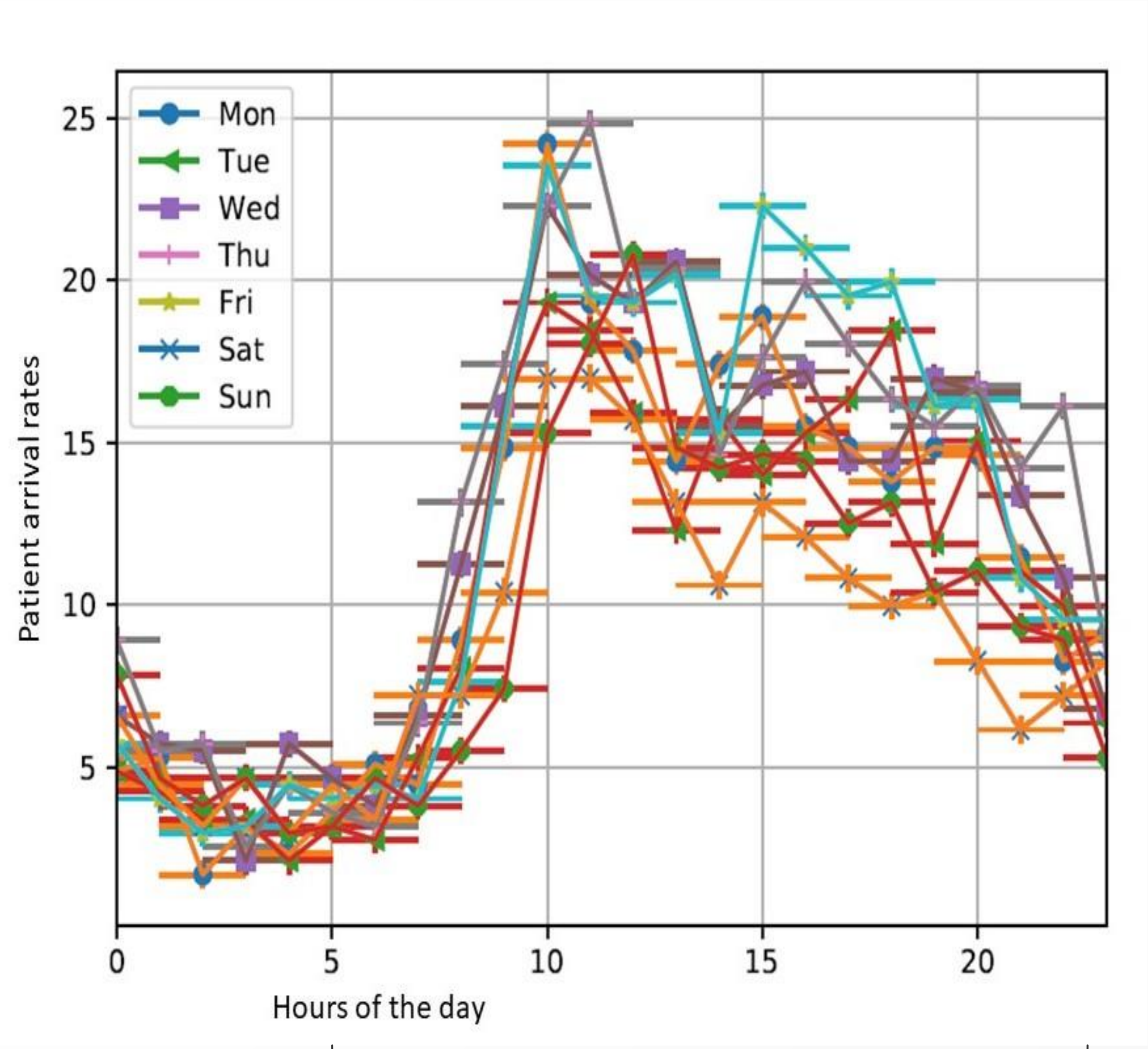
Characterization of patients entering the hospital

- The patient arrival rates distribution along the hours of the day.



Characterization of patients entering the hospital

- The patient arrival rates distribution along the hours of the day.
- The range of approximately 5 to 22 hours is the range where patients go to the hospital the most.

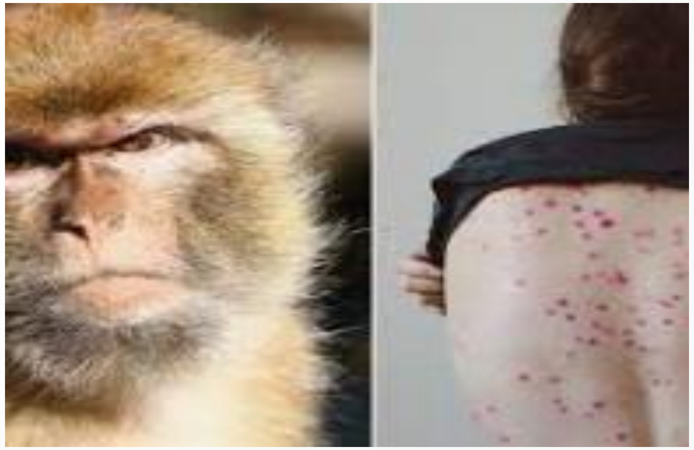


Conclusion

- This paper presented **the modeling of an emergency department in the presence of a pandemic** using the agent-based model.
- **A set of synthetic input data has been prepared for the simulation**, which is why the distribution of arrival patients had to be generated. COVID and NO COVID with different levels of severity and the general distribution of simulated patient ages.
- **Simulation can be an essential component of a decision support system (DSS)** to help hospital administrators and those responsible for the emergency department achieve a better patient care cycle.

Future work

- Our future work is to add more details to the agent-based simulator to **make it as consistent and close as possible in a pandemic situation**.
- Make a digital **twin of the Hospital** to validate and generate different scenarios
- We need to make it more flexible; It can help us a priori in case another pandemic arises



Thank you!!!.

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