The Sixth International Conference on
Advances in System Simulation (SIMUL 2014)

A Generalized Agent-Based Model to Simulate Emergency Departments

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OUTLINE

- Introduction of Emergency Department (ED); *What?*
- Model of Emergency Department; *How?*
- Possibility of the Simulator;
- Conclusion and Future work. *State?*

INTRODUCTION

➢Emergency Department (ED) is the main entrance to healthcare system, the Efficiency and Quality of Service in ED has big influence to the whole healthcare system.

➢Patients arrive the ED without prior appointment, some of them with unstable conditions and must be treated quickly!

➢EDs are overcrowded and work with limited budget.

➢ED is a complex adaptive system!

➢… …

Problems to solve

How to solve these problems?

To make decisions to solve these problems, there are many questions should be answered first to support the decision, e.g.:

- If the number of arrival patients doubled, what will happen?
- If we increase 20 more careboxes, the overcrowd can be solved?
- The budget decreased, how QoS will be affected? which staff can be reduced? doctor? nurse? ... ?
- … …

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How can we know the effect of a decision without the commitment of any physical resources or interruption of the system?

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Simulation

What is an ED simulator?

☞Emergency Department:

- Complex system.

☞Model:

- **Agent based model**;
- Generalized and Adaptive.

☞Execution:

- Model was implemented on Netlogo;
- HPC is used to deal with massive data and computing;
- HPC was used to simulate different scenarios

THE ED SIMULATOR WE HAVE NOW

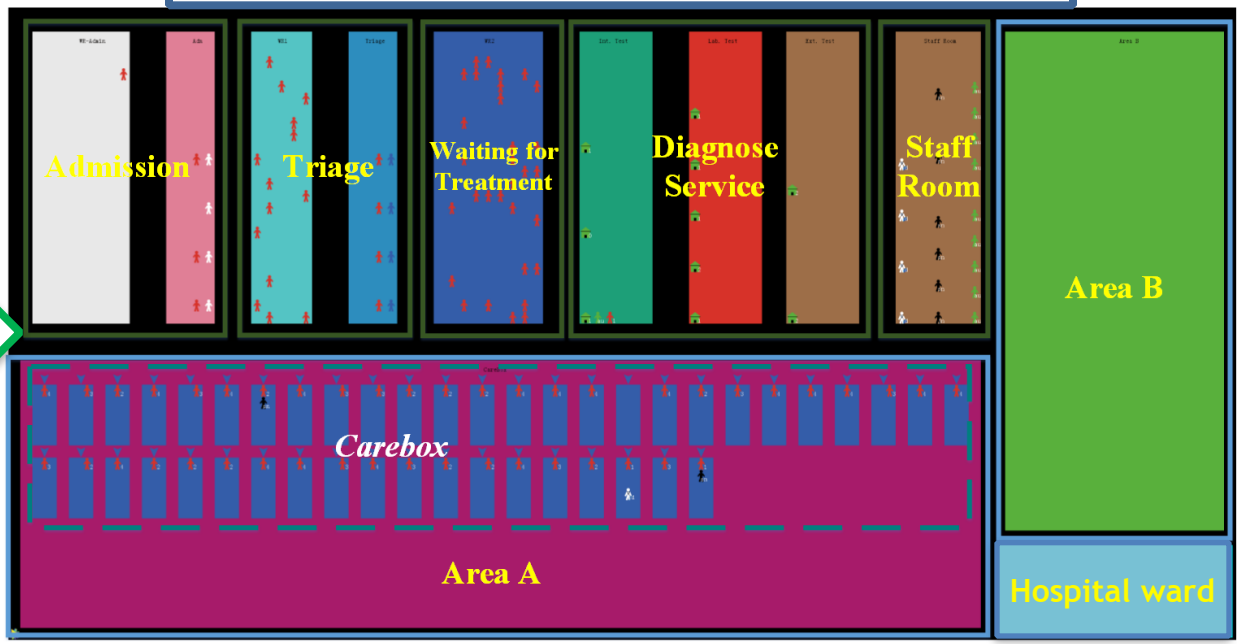
patient(input)

configuration

- ✓admission staff
- ✓triage nurse
- ✓nurse
- ✓doctor
- ✓auxiliary
- ✓carebox
- ✓laboratory test
- ✓internal test
- ✓external test
- ✓hospital ward
- ✓ambulance.
- ✓…

scenario

Two areas: A and B for different patients



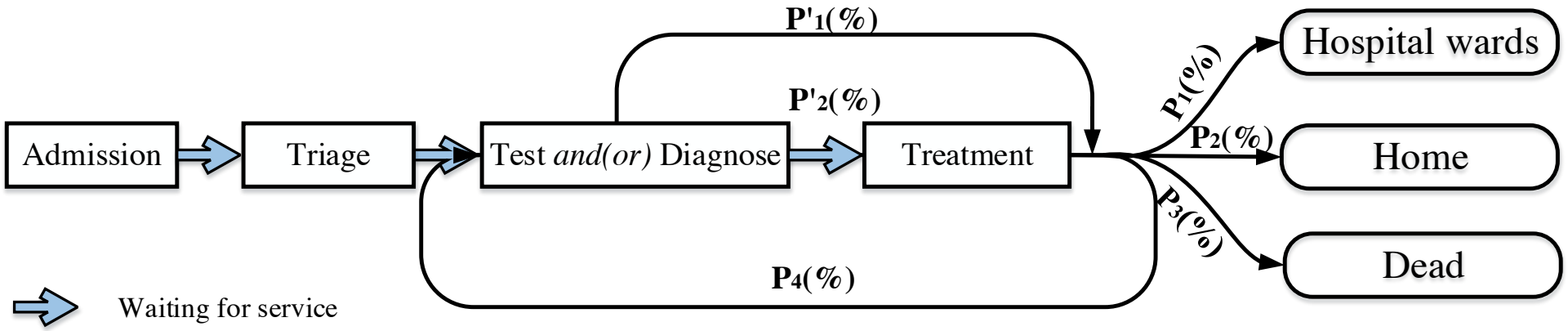
Version 2.0

acuity level: 1 → 5

Patient:

The simulator is not dedicated for any specific ED, that can simulate other EDs who works under the similar healthcare policy by tuning process (adaptable).

General process of patient in ED



$$P_i = f(LOS, age, level)$$

$$\sum_{i=1}^{4} P_i = 100\%$$

$$P'_i = f'(ToT, age, level)$$

$$\sum_{i=1}^{2} P'_i = 100\%$$

Execute several times to make result statistically reliable

Parameters for the probability distribution function:

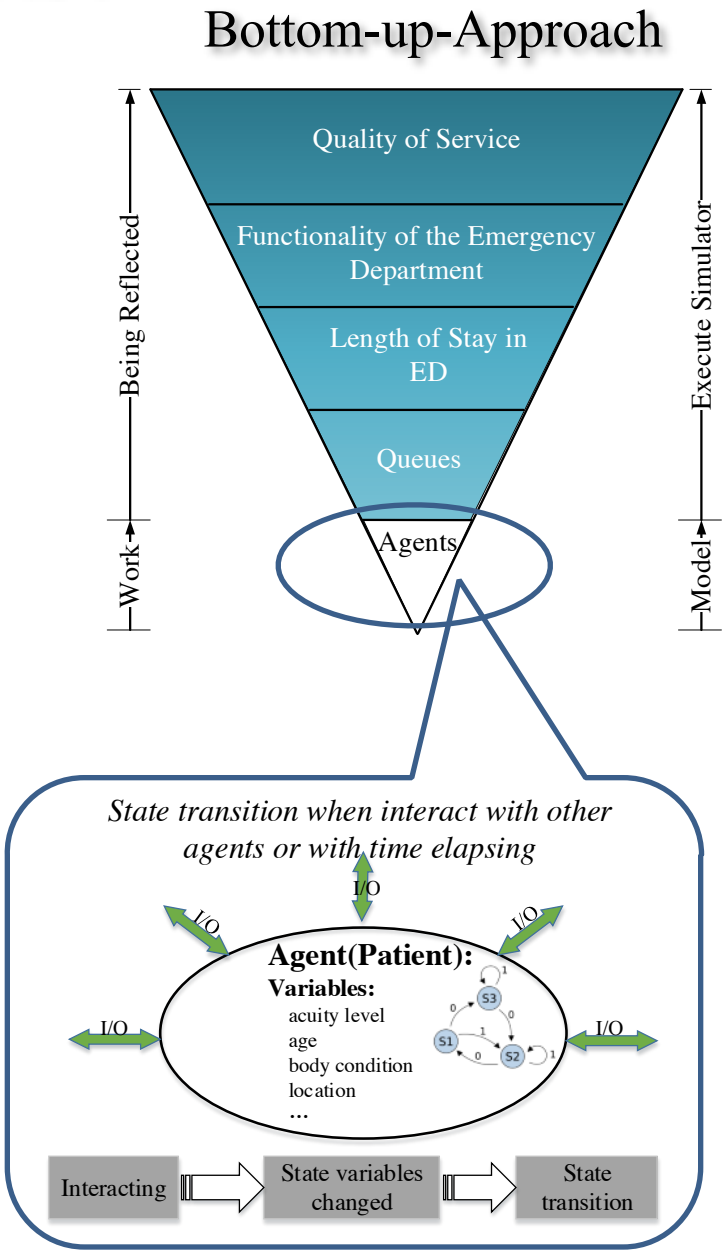
LOS => the patient's length of stay in the carebox.

age => the age of the patient.

level => the acuity level of the patient.

ToT => the type of test and (or) diagnose.

How it works?

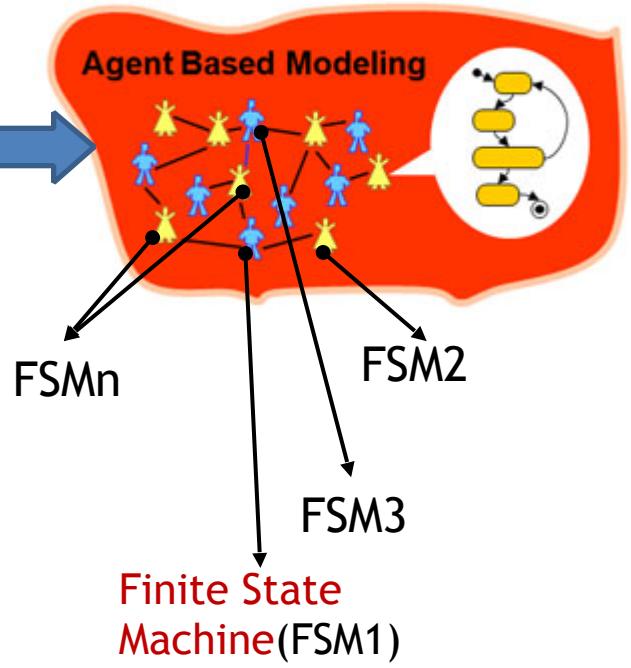

Bottom-up-Approach
Quality of Service
Functionality of the Emergency Department
Length of Stay in ED
Queues
Agents
Being Reflected
Work
Execute Simulator
Model
State transition when interact with other agents or with time elapsing
I/O
Agent(Patient):
Variables:
acuity level
age
body condition
location
...
S1
S2
S3
Interacting
State variables changed
State transition

How it works?

Scenario | **Interaction** | **Behavior**

Patients

- Sanitary staff
- Physical Resources
- …



Interact information

Reflect

Configuration

Functionality

AGENT DEFINITION

Agent $A = \{V \cup B\}$

State $V = \{V_1, V_2, \ldots, V_m\}$

Behavior $B = \{B_1, B_2, \ldots, B_n\}$

State Variable $V_i = \{Y_1, Y_2, Y_3, \ldots, Y_{K_i}\}(0 \leq i \leq m)$

State transition $Y_{K_i} = f(B_j, T)(0 \leq i \leq m, 0 \leq j \leq n)$

AGENTS AND THEIR ABSTRACT BEHAVIOR:

Table 1: AGENTS AND AGENTS' BEHAVIOR

Agent	**Behavior**
Patient	Waiting for service. Accepting service. Waiting for treatment takes effect.
Admission Staff	Provide admission service for patient. Waiting for next patient.
Triage Nurse	Provide triage service for patient. Waiting for next patient.
Doctor	Look over test result. Provide diagnostic service. Arrange test for patient. Arrange treatment plan. Waiting for task.
Auxiliary Staff	Moving patient to the specific place. Waiting for task.
Nurse	Take and send samples for laboratory test. Provide treatment service. Waiting for task.
Laboratory Test	Accept sample from nurse. Analyze samples of patient. Send analyzing result to the corresponding doctor. Waiting for samples.
Internal Test	Provide test service. Send analyzing result to the corresponding doctor. Waiting for next patient.
External Test	Provide test service. Send analyzing result to the corresponding doctor.
Ambulance	Providing service to patients. Waiting for task.
Carebox	Providing treatment place to patient. Waiting for next patient.

An example of a patient's state transition

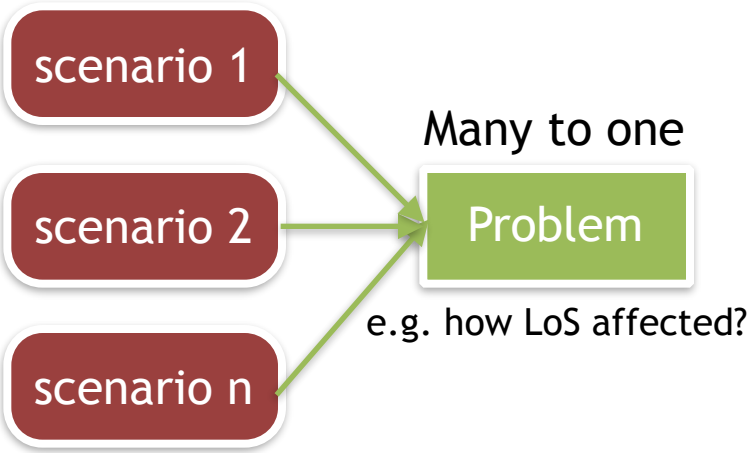
Table 1: A part of a patient's state transition.

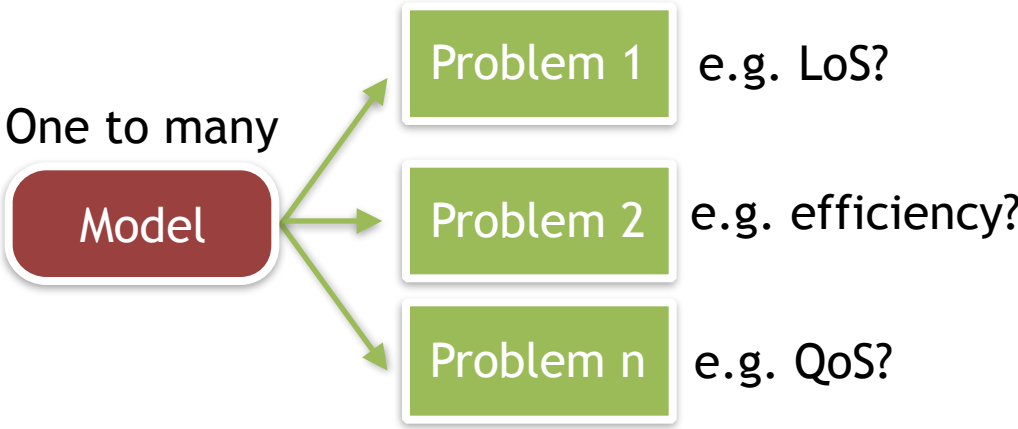
State index	**Source State**	**Destination state**
...	...	...
S_t	Waiting for service (free carebox).	Waiting for service (Doctor's diagnosis).
S_{t+1}	Waiting for service (doctor's diagnosis)	Accepting Service(meet with doctor)
S_{t+2}	Accepting Service(meet with doctor)	Waiting for service (X-Ray test service)
S_{t+3}	Waiting for service (X-Ray test service)	Accepting Service(X-Ray test service)
S_{t+4}	Accepting Service(X-Ray test service)	Waiting for service (Doctor's review of the test res
...	...	...

What can we do with the ED-simulator?

HPC makes it possible:

- High Performance can provide abundant computational resources and store/process massive data.





What do we plan to do:

- We describe an agent based model of an emergency department and its utility for evaluating decision/changes. (**decision support**)
- Help us to better understand and manage emergency departments. (**discovery knowledge of ED**)
- Provide a **platform** for ED related problem studying.

POSSIBILITY OF SIMULATOR

Virtual ED

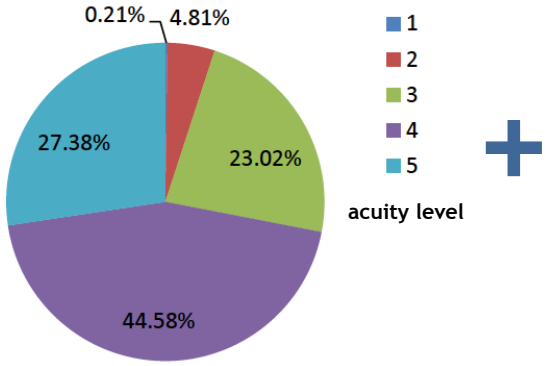
Simulation condition:

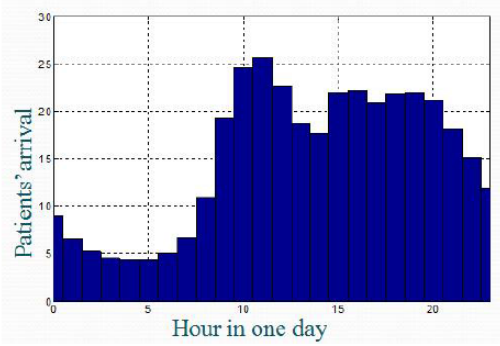
Simulation Time: 720 hours(30 days)

Execution Time: 3 minutes per one scenario

Patient arrival (input)

Real Data from Hospital of Sabadell



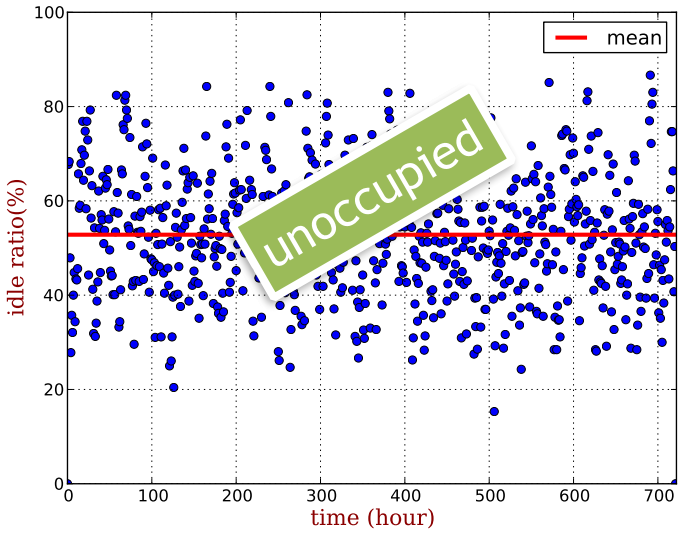


397 patients / day

Scenario configuration

name	*value*	meaning
n-of-adm	***4***	admission
n-of-tn	***4***	triage nurse
n-of-jnA	***1***	junior nurse in A
n-of-snA	***7***	senior nurse in A
n-of-jnB	***1***	junior nurse in B
n-of-snB	***2***	senior nurse in B
n-of-jdA	***3***	junior doctor in A
n-of-sdA	***3***	senior doctor in A
n-of-jdB	***2***	junior doctor in B
n-of-sdB	***2***	senior doctor in B
n-of-auxi	***10***	auxiliary
n-of-cb	***60***	carebox
n-of-int-tr	***4***	internal test room
n-of-lab-td	***9***	external test room
n-of-ext-td	***3***	lab. test room
n-of-amb	***8***	ambulance
area-B-cap	***70***	capacity of B

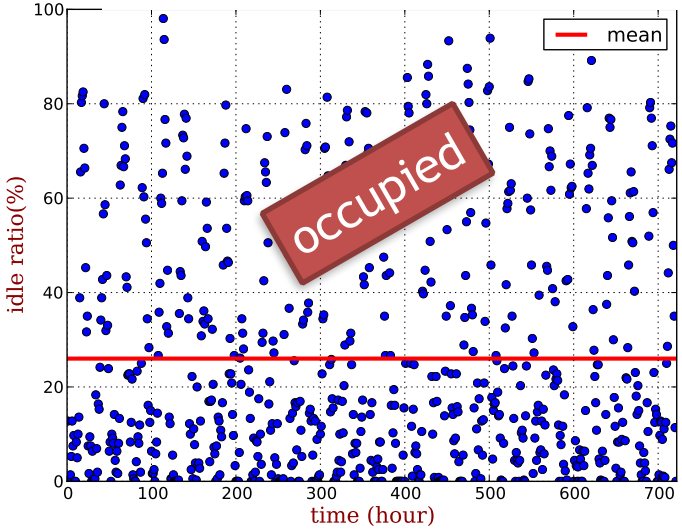
Nurse in area A



n = number of nurse in area A

Workload of sanitary staff

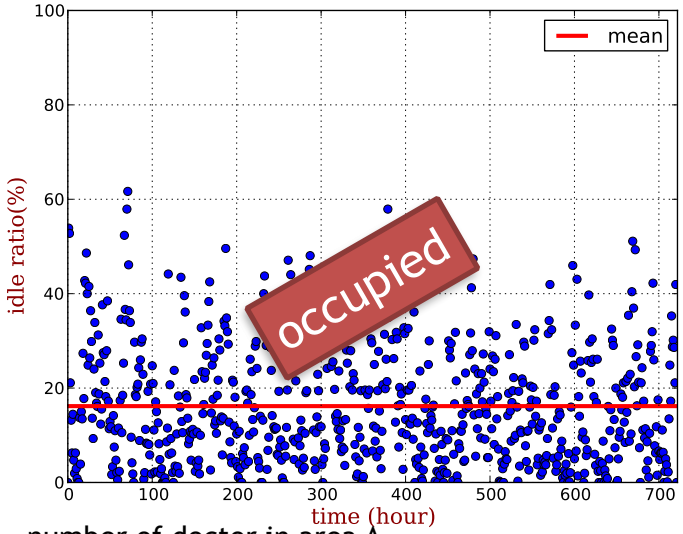
Nurse in area B



n = number of nurse in area B

$$idle\_rate = \frac{\sum_{i=0}^{n} length\_of\_idle\_time}{n \times length\_of\_working\_time} \times 100\%$$

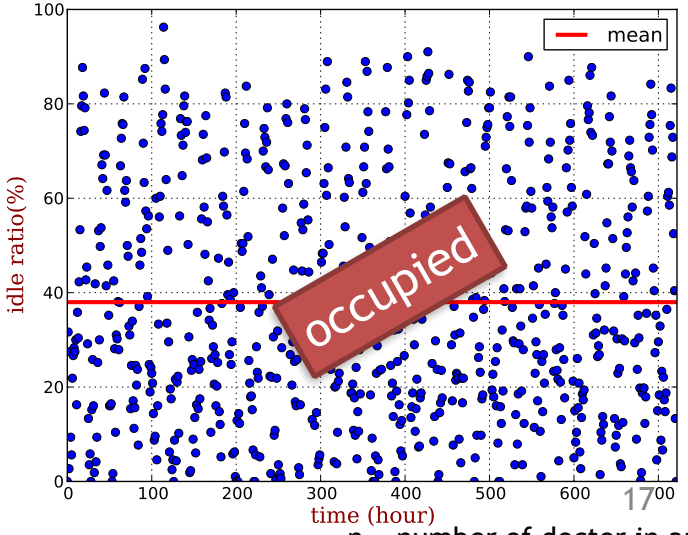
Doctor in area A



n = number of doctor in area A

Efficiency

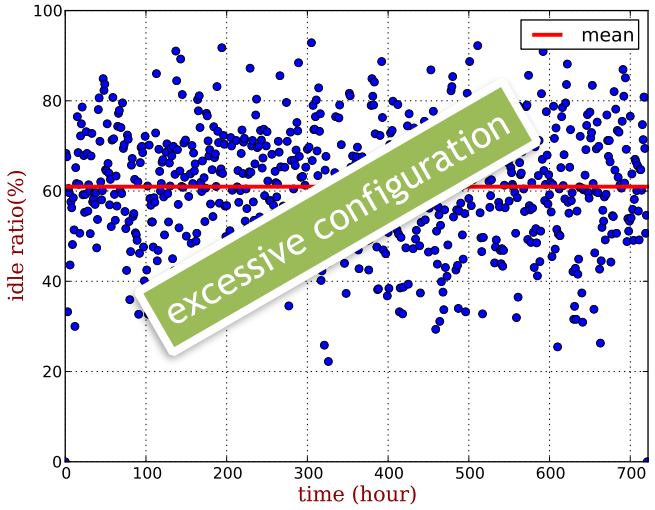
Doctor in area B



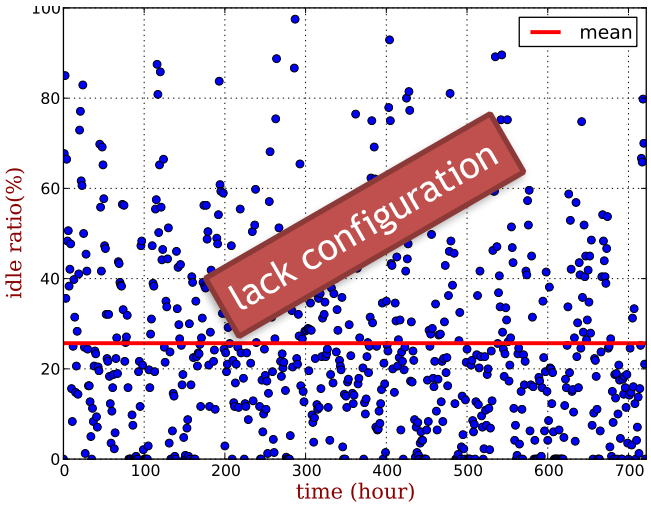
n = number of doctor in area B

Workload of physical resource

Laboratory test

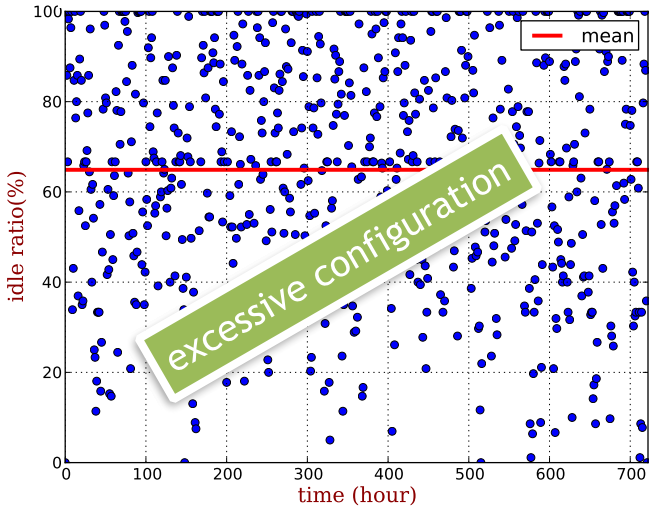


Internal test



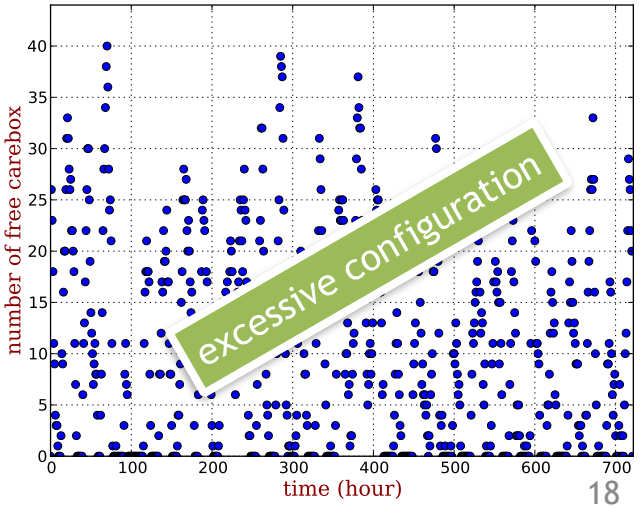
$$idle\_rate = \frac{\sum_{i=0}^{n} length\_of\_idle\_time}{n \times length\_of\_working\_time} \times 100\%$$

External test



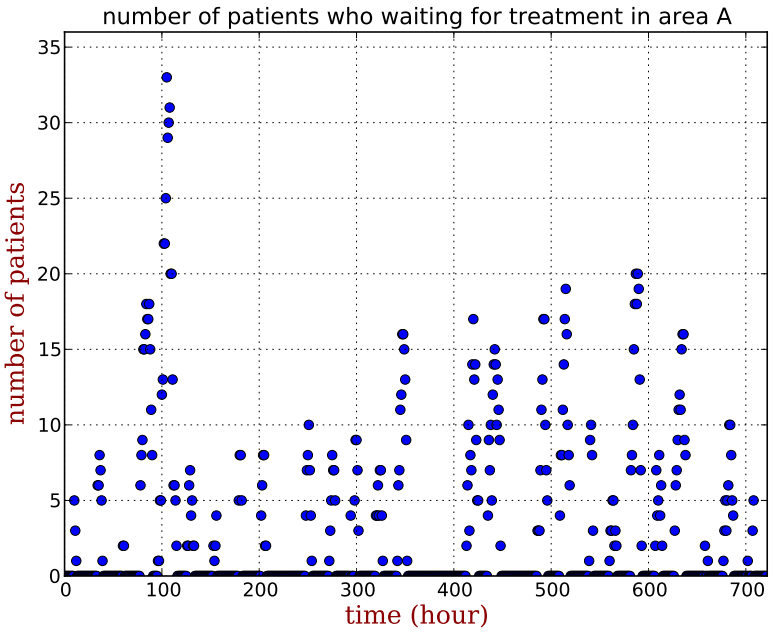
Efficiency

Carebox

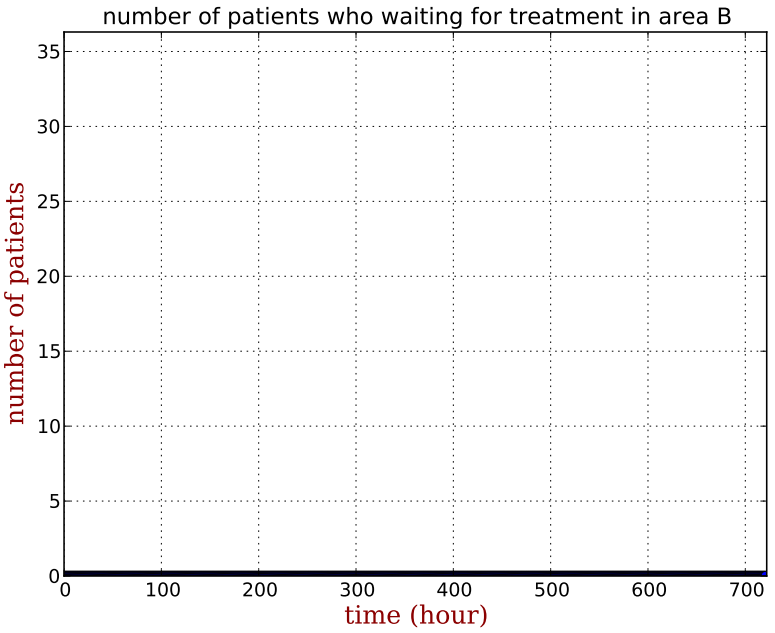


Number of patients in waiting room

urgent patients(acuity level 1,2 and 3)



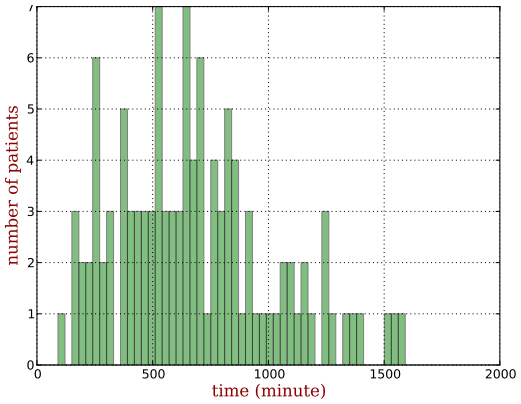
non-urgent patients(acuity level 4 and 5)



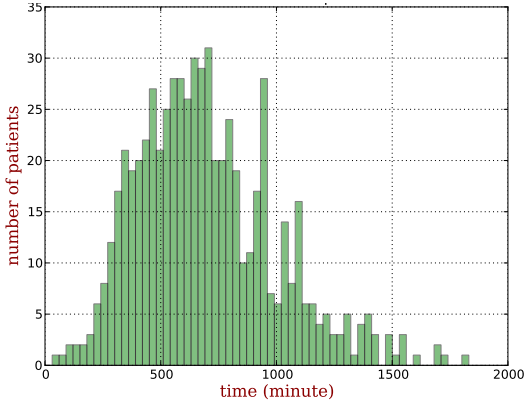
Utilization

Area A

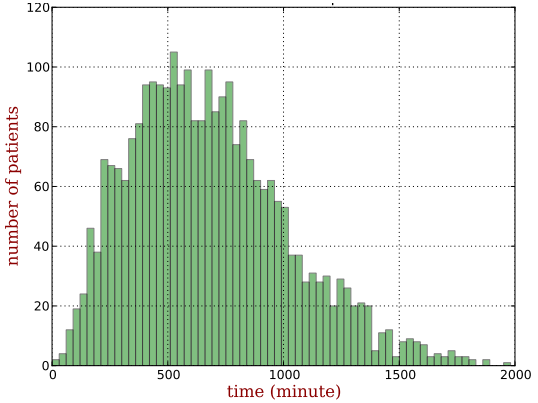
Patients with acuity level 1



Patients with acuity level 2



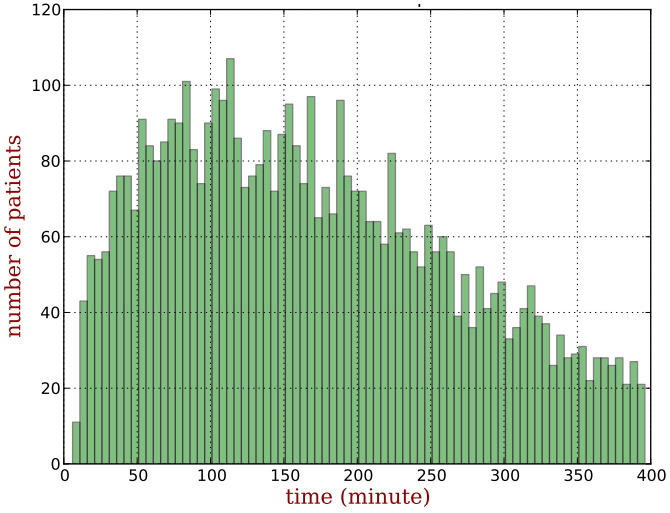
Patients with acuity level 3



LoS distribution

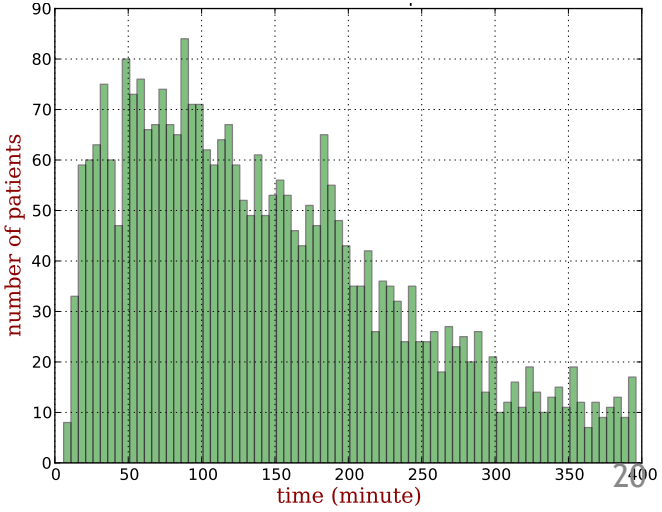
Area B

Patients with acuity level 4



QoS ?

Patients with acuity level 5



Conclusion and future work

- First, we created a generalized agent-based model of ED and implemented the model in Netlogo simulation environment.
- Then, we performed verification to debug the model and ensure that it performed as intended.
- Next, we will complete validation of the model to ensure that it behaved as it would **in real life** and that it accurately represented the patient flow at Emergency Department.
- Perform data mining to discover interesting knowledge about ED and try to answer some interesting question for decision making.

RELATED PRESENTATION IN SIMUL2014:

High Performance Computing for Efficient Applications and Simulation Research Group(HPC4EAS)
http://grupsderecerca.uab.cat/hpc4eas/

- Modeling the Contact Propagation of Nosocomial Infection in Hospital Emergency Department. **Tuesday**, October 14, 10:30 - 12:15; **SIMUL 4**

- Simulation as a Sensor of Emergency Department: Providing Data for Knowledge Discovery. **Thursday**, October 16, 09:00 - 10:45; **SIMUL 9**

Thanks for your attention!!

Questions?

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