MODELLING AND SIMULATION OF THE OPHTHALMOLOGY SERVICE FOR RMUHO

Khaled BELKADI
LAMOSI, University of Mohamed Boudiaf, USTO,
BP 1505 Oran M’Naouer, 31000 Oran,
ALGERIA
E-mail: belkadi1999@yahoo.com,
belkadi@isima.fr

Alain TANGUY
LIMOS, CNRS UMR 6158, University Blaise
Pascal, Les Cézeaux, 63173 Aubière Cedex,
FRANCE
E-mail: tanguy@isima.fr

Abstract: - The aim of this paper is to model and simulate the ophthalmology service of Regional Military and University Hospital of Oran (RMUHO) in Algeria using ASDI methodology (Analysis, Specification, Design and Implementation). Ophthalmology is a medical science apprentice of anatomy, diseases, vision disorders, eye therapy and its annexes. The ophthalmology service is an essential unit and occupies an important place in hospitals. This study focuses on the functional exploration of the ophthalmology service and mainly on the simulation of units for consultation, examination and care. The objective is to study the utilization rate of rooms and doctors of ophthalmology service, and to increase its quality of service. For this, we first use the ARIS tool to specify the knowledge model and then we simulate models thanks to the SIMULA language and the Witness tool to implement action models. We have thus completed the transition from a knowledge model to action models. We obtained simulation results that we discuss and we propose an enhancement of the appointments process.

Key-Words: - Hospital, Ophthalmology Service, Exploration Unit, ARIS Modelling, SIMULA and Witness models, Discrete-event simulation

1 Introduction

Hospital systems are complex systems in which problems have to be solved such as the size and number of their critical resources, the enhancement of their efficiency or obviously the understanding of their operation. These problems concern performance evaluation; they can be solved using modelling and simulation. Modelling is a decision aid tool that prevents important financial investments.

This paper describes the modelling and the simulation of the ophthalmology service in the hospital system. The ASDI (Analysis, Specification, Design and Implementation) [10] modelling methodology is adapted and used for this system. It is based on the construction of two model classes: the knowledge model and the action models.

The aim of this work is to model and to simulate the ophthalmology service of the Regional Military and University Hospital of Oran (RMUHO), following ASDI methodology, using ARIS tool (Architecture of Integrated Information System) [24] for the knowledge model and the SIMULA language and Witness for the action models.

The paper focuses on the ophthalmology service. It is one of providing services of the RMUHO [5, 21]. It is organized into three sub-services [3]:

- Sub-service of functional exploration: home sick, consultation and exploration box (Angiography, Laser, Electrophysiology, Ultrasound and Orthoptic Unit)
- Sub-Service Emergency: consisting of a consultation box for patients.

This study focuses on the exploration of the ophthalmology service and mainly on the simulation of consultation, examination and care units. It is therefore a consultation room, five examination rooms and a care room, equipped with their own material resources and personnel...

Our goal is to model and simulate the ophthalmology service in order to study the utilization rates of rooms and doctors of this service.

For this, we first present the ophthalmology service and its problems [1, 3], the modelling methodology [7, 10] implementation and the modelling of this activity with the ARIS tool, and simulation models based on queueing networks. The first, implemented in SIMULA with Gpsss class, follows a transaction while the second is done using the simulation tool, industrial area, Witness, which uses a station approach and offers possibilities such graphs interface for developing and running the model.

2 RMUHO Ophthalmology service

Regional Military and University Hospital of Oran (RMUHO) has been in operation since January 2005 [5, 21]. This hospital complex is located at the
southern outskirts of the city of Oran, on an area of 40 ha and includes the following: Hospital, Heliport, Sport Complex, and a city of 300 apartments. The RMUHO in Oran incorporates several administrations and services [3, 19] among them there is ophthalmology service [2].

Ophthalmology is a medical discipline to the evaluation and correction of vision problems [4]. The ophthalmology service deals with all diseases of the eye sphere relating to inpatients and outpatients of RMUHO. The ophthalmology service is composed of the exploration sub-service and essentially consultation unity with a consultation room, the review unit with five examination rooms and an intensive care unit with a care room. These units are equipped with their own material resources and personnel. The complete ophthalmology examination includes examination of the patient and a physical examination.

3 Modelling methodology
The modelling methodology ASDI (Analysis, Specification, Design and Implementation) has been adapted to hospital systems [7, 11, 12, 13]. The knowledge model describes the structure and the operating principle of the system in a natural or graphical language; it is built thanks to three subsystems (logical, physical and decisional). An action model is a translation of the knowledge model in a mathematical formalism or in a programming language enabling the evaluation of chosen performance criteria.

The main goal of the modelling methodology is to establish a knowledge model that is as generic as possible and that allows the execution of the action models specific to the systems of the domain. The knowledge model remains an open model which is enhanced by each domain systems study. The management of the knowledge and the execution of the action models imply the help of an open modelling environment in order to include new and more efficient methods and tools. The modelling environment (figure 1) eases information exchange between the project members and helps the conception of action models during the extraction of the information from the knowledge model.

It's an attempt to introduce automatism in the modelling process with the formalization of the knowledge, the analysis of the data to determine the characteristics of the system, the operational research and the simulation for the evaluation. Graphical representations and animation tools help verifying proper operation of the model.

4 Modelling process
Modelling is a set of techniques that provides the ability to study and understand the structure and the operating principle of a system. We use three rules to build a model that represents the reality: a model must be alike to the reality, a simplification of the reality and an ideal view of the reality. Figure 2 describes the modelling process.

The first knowledge model of the hospital logical system has been formalized thanks to the ARIS tool (Architecture of Integrated Information System) [24] that is appropriate to describe organizations, processes and activities [14], as well as entity-relationship models [6].

![Fig.1: The modelling environment](image1.png)

![Fig.2: The modelling process of a system](image2.png)
directly usable and states the performances of the modelled system without using direct measure.

Exploitation of the knowledge model and of the action model is called modelling process. This process is generally iterative and consists in four steps which are the elaboration of a system knowledge model, the translation of this knowledge model into an action model, the exploitation of the action model to evaluate the performances of the system and the interpretation of the results and consequently to deduce the modifications to be made on the system. Each step includes a verification and validation phase. A knowledge model has a wide application area.

In order to use ARIS to design a knowledge model [15, 20], several modelling hypothesis are to be taken into account:
- Each activity (function in ARIS) is linked to one or more organizational units of the hospital system (care unit, operating room, the pharmacy, the stomatology service, ophthalmology service, etc.);
- Each event possesses its own information document, it is used by several processes and it is referenced in one or more documents of the information system (medical file of the patient, file of the operating room suite, etc.);
- The referenced documents provide the knowledge concerning the key processes.

To match our modelling goals, we chose the ARIS tool-set and we retain two representation types [15, 22, 23, 24]:
- The event-driven process chain (EPC) in order to show that the processes have a well defined structure and to control the logical subsystems flows;
- The organizational structure for the decisional subsystem to detail the relationships in and between the services.

5 Knowledge model event-driven process chain (EPC)
The sequence of functions in the sense of an enterprise process is represented in process chain. In these chains, it is possible to indicate the departure and arrival events for each function. The events trigger functions and they are generated by them. Event-driven process chain (EPC) represents the organizational structure of the enterprise, i.e. the representation of the relationships between the data view, objects, the functions and the organizational views.

An EPC describes the sequencing of functions. For each function, an initial event and a final event are defined. The events trigger the functions and a function generates events. Function and event are represented by a rounded rectangle and a hexagon (figure 3).

As the events define the state or the condition that triggers a function as well as the end state, the start and end nodes of an EPC are always events. An event can trigger several functions simultaneously and a function can provoke several events. To represent the links and the processing loops of an EPC, the system uses a connector (or ruler) which is the shape of a circle.

Figure 4 shows the specification of the ophthalmology service by an EPC. Two connectors (inside ellipses) are used: an And operator and an Exclusive Or. The And operator insures that only an arriving patient having a recorded rendezvous may be processed. The Exclusive Or connector allows a patient to select only one specialty, this corresponding to the rendezvous.

The operation principle of the ophthalmology service is the following [17, 2]:

Patients randomly arrive from medical centres social or military units in SCC (Specialized

![Fig.3: Event and Function](image1)

![Fig.4: Ophthalmology service EPC](image2)
Consultation Centre), where they will be greeted by an ophthalmologist for a consultation. According to the health of the patient, the doctor may treat the patient or to fix an appointment at the RMUHO.

Once in the RMUHO the patient arrives at the admissions office to get the card shuttle. Then after his appointments, he will be directed to the correct service (exploration or hospitalization in ophthalmology).

At the hospital service of the ophthalmology, the patient will be scheduled on a given date to reserved operating room of Ophthalmology.

### 6 Action models

The ophthalmology service action (or simulation) model of the “Regional military and University Hospital of Oran” (RMUHO) is represented by the SIMULA and Witness models.

#### 6.1 Queueing network model

Figure 5 shows a queueing network model that represents a general action model of the ophthalmology service.

We model three units or sections: review units, consulting unit and care unit. The entire mission of the review unit of the exploration service of ophthalmology includes the following times; the same approach applies to the consulting unit and the care unit:

- A secretary is responsible for the reception and the dispatching of patients;
- The patient waits in the waiting room until resources are released (free room and staff);
- In order to treat the patient a dedicated room must be available and prepared (preparation time);
- An ophthalmologist performs the treatment needed by the patient, interprets the results and delivers them to the patient;
- Finally the staff and the room are released.

#### 6.2 SIMULA model

The SIMULA language has proved its capacity to implement different simulation models categories [8]. It includes co-routines and processes of discrete events simulation. Numerous classes exist that extend the language possibilities regarding transactions management and statistical computations. The Gpssss class provides base objects such as the service, the storage, the transaction notions as well as the statistical region. Moreover, a simulation report is generated automatically. This class can therefore be used in GPSS programming with all the object-oriented capacity of a simulation language.

#### 6.3 Witness Model

Some parts of the hospital system are specified with the UML language [9, 16]. An additional simulation module is available to ARIS, but we need graphics and especially 3D animation. Witness simulation tool was initially preferred to develop animated simulations of action models [18].
7 Results, interpretation and correction
We obtained results with the simulation of SIMULA and Witness that we compared with data taken on a real case of the ophthalmology department of HM RUO [1].

SIMULA model of exploration service
The obtained results with models written in the SIMULA language and using Montréal Gpss class are given in figure 6.

*facilities*

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<th>Average time transit</th>
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*storages*

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<td>28.31</td>
<td>1</td>
<td>3</td>
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*regions*

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<th><em>regions</em></th>
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<td>5.00</td>
<td>1</td>
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<td></td>
</tr>
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<td>0.00</td>
<td>1</td>
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<td>0.00</td>
<td>0.00</td>
<td>1</td>
<td></td>
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</tr>
</tbody>
</table>

Total number of patients: 25
Review: 6
consultation: 10
Care: 9

Fig. 6: SIMULA results of exploration service

A secretary is responsible for the reception of patients; its activity is described by a term following a uniform law [1, 5] and occupies 18% of its working time. The three nurses are shared resources between care and cooperation of the ophthalmologist for the various examinations. The installation time of the room has been chosen constant (5 minutes), its occupancy time is low in the Exploration 30.14% (preparation of room 9.92 + Care 20.22) as it performs other useful complementary tasks.

The occupancy rate of rooms is between 13.08% and 47.29%, and the teams between 20.22% and 76.20%. The duration of consultations, examinations care and interpretations were considered uniform in intervals depending for exploration service and parameters used are summarized in Table 1 [2]:

<table>
<thead>
<tr>
<th>Caracteristics of exploration service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to act (minutes)</td>
</tr>
<tr>
<td>Review</td>
</tr>
<tr>
<td>Consultation</td>
</tr>
<tr>
<td>Care</td>
</tr>
</tbody>
</table>

Table 1: Characteristics of exploration service

For the object region, we used the following parameters that provide statistics on waiting on the units:
- AttenSURE: provides the average number and average length of stay by serving of patients in the exploration ophthalmology.
- AttRoom: the average waiting time for a free and prepared room.
- AttPersonal: the average waiting time of a personal: medical (ophthalmologist) or paramedical (nursing).

From the obtained simulation results we can decide and suggest what to do to improve some units.

In our case we note that the occupation rate of the examination room is lower (13.08%) compared to occupancy of the review team which is 76.20%. This value shows the lack of a sufficient number of personnel who perform this task, and have a better case, we assume that examinations are conducted by 5 personnel depending on the capacity of the review unit and we find the following results given in Figure 7:

Fig. 7: SIMULA results of exploration service after modification

Is it enough to give reasonable conclusions? Surely no! It is due to the lack of confidence intervals. The previous simulation stops at 420 minutes (7 hours working time) but the treatments are continued and a valued result concerns the total time necessary to treat all the patients (makespan in manufacturing context). So we need to provide statistics and confidence intervals concerning: the total processing time, personnel working time and room occupancy time. The occupation rates will be corrected to take into account a longer working time. The factor is given by: 420/SimulationTime.

The replication method (100 independent simulation runs) and the Student probability distribution provide that we need. The previous model is modified so as to stop when the last patient goes out
of the service. It is possible with a SIMULA trick, we reference:

TheMainProcess :- current;
in the initialization part of the simulation. And we test:
If Nextev == TheMainProcess then
Reactivate TheMainProcess;
at the end of the Patient transaction.
We added statistics computation about the processing durations. Each simulation records statistics into a file that can be converted into a CSV file and processed by OOo Calc or Excel. Figure 8 shows the statistics. Nb is the number of replications or entries and the confidence intervals are defined by [LowBd, UpBd] with a 5% risk. Personnel resources are prefixed by P and rooms by R.

<table>
<thead>
<tr>
<th>Nb</th>
<th>MeanV</th>
<th>StdD</th>
<th>Wid/2</th>
<th>LowBd</th>
<th>UpBd</th>
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</table>

**Figure 8:** 95% confidence intervals

**Witness model of exploration service**
Witness model provides a graphic animated representation of Ophthalmology service (figure 9).

![Witness model of exploration service](image)

**Table 2: Witness software components**
From examinations scheduled and appointments given to patients, the secretary (its work is described by a stochastic process following a uniform law (1, 5)) will host the patients and dispatch them to the destination service. In each destination there are resources providing service. These resources are allocated to patients when they are available, otherwise the patient will wait for the resources to become free.

<table>
<thead>
<tr>
<th>Time</th>
<th>Review Med1</th>
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<th>Consultation Med1</th>
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<td>1</td>
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</table>

**Table 3: Parameters and values used in Witness**
The obtained results with the Witness model are given in Figure 10 and Table 4.
Witness provides reports and statistics but no confidence interval.

The previous SIMULA model was very quickly modified to simulate the service with a planning of appointments as input. It takes into account 2 identified generalists for review and consultation. As for the Witness model, the examination and the report writing are grouped in a single uniform process. But it is easy to design and to implement a more complex behaviour of the service.

Comparison of both models
Despite of the difference of the models we give some regarded aspects in decision aid. The results of action models of exploration service of ophthalmology concern the following cases:
- When we seek to increase the utilization rate of resources, we are more interested in the proportion of time during which resources are available compared to the time when they are occupied, during the given simulation period (TMax = 420 minutes) and we have to regard the possible overload (SimTime > 420 minutes). The new SIMULA model provides a makespan belonging to the interval [369.76 ; 380.12]. In Table 5 and 6, SIMULA model occupancy rates are computed for a group of same resources. There are two used rooms (among 5) for review and Witness model gives the rate for one room. For consultation room 80.10% is low because one patient does not finish the consultation.

### Table 4: Witness results of the exploration service

Note: The occupancy rate of the teams is given by the occupancy rate of the rooms or group of rooms (review).

The main goal for this model concerns the simulation animation. But, at time 420, we may remark:
- One consultation article is ever in RoomCons;
- For the secretary:
% disp + % cycle occup ~ 30 < 100
thus the secretary is blocked in service and patients are delayed.

Somebody forgot to build a waiting room for the patients between secretary room and treatment rooms. This model offered a too much simplified view of the exploration service. It is possible to watch the animation of the simulation and to verify the blocking of the secretary. Concerning simulation results,
When we want to avoid losing patients because the queue is long, we will have to decrease the waiting times.

From these values, we may say that the obtained results by simulating the exploration service of ophthalmology are close to those of reality for 26 patients [2].

Quality enhancement of appointments
The SIMULA model has been developed to provide specific results, makespan and confidence intervals, which computation is based on the replications of a simulation using system parameters and a list of appointments. It is adapted to the management of the list of appointments in real time. For 100 replications, the CPU time is short, less than 1 second on a compatible PC with a CPU Atom at 1.6 GHz.

When a new patient is added to the list the makespan interval is quickly computed in order to determine if the last patient can be treated before a given time so as to avoid late working. The appointment may be modified or differed at another day. Several objectives can be reached:
- balance de utilization rate of medical personnel,
- minimize patient waiting times,
- optimize the room utilization…

8 Conclusion
We have contributed to the study of the ophthalmology service of Oran RMUHO which generally has not been taken into account in hospital studies. The main problem is the study of utilization rate of rooms and doctors of this service.

The methodology proposes the sequential and iterative construction of two models: the knowledge model (formalization of the structure and operation of the system) and the action model (simulation models in our case, in SIMULA and Witness). We noted that the results obtained with Witness are not so far from real data. The SIMULA models provide generic and specific results, statistics more suitable for a stochastic process study. For this, we suggest to add more work at the entrance to this service because it can take them into account.

An important study concerns the enhancement of the appointment list that could be optimized to insure better work and service quality. A coupling of the SIMULA model and a heuristic method will help to increase the system performances.

Several research topics can complete this work: modelling and simulation of other hospital departments, the use of other tools for modelling and simulation, study of the planning services of the hospital and steering hospital systems.

References:


