

# HEAT: A Tool to Develop, Analyze and Monitor Clinical Guidelines

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**Abstract**—HEAT (*Healthcare Efficiency and Effectiveness Analysis Tool*) is a software application developed to support designing and analysis processes of the clinical guidelines. It was developed in collaboration with the Hospital “Lozano Blesa” in Zaragoza. HEAT is composed by two different tools. The first one, called *HEAT-Scenario Designer*, can be used to: (a) design new clinical scenarios, (b) check the correct use of resources and (c) check the correct communication strategies between several clinical guidelines. To model clinical guidelines, HEAT uses a domain specific modeling language (DSML), called Healthcare System Specification (HSS), being defined as an Unified Modeling Language (UML) profile. This language lets the medical personnel to describe the system without any knowledge of UML or other mathematical theory. Then, the tool can be used to transform the clinical guidelines to Stochastic Well-formed Nets (SWN), a formal model that can be used latter for analysis by using available packages. The second tool of HEAT, called *HEAT-Patients Monitor* can be used to monitor the flow of patients that follow the modeled clinical guidelines inside the hospital, providing to the medical doctors useful information about the behavior of the clinical guidelines.

## I. INTRODUCTION

The medical staff working in a hospital is following during its working day *protocols* or *guidelines* (CGL) [1]. For each disease, operation or medical procedure there exists a clinical guideline to describe the sequence of treatments, medical analysis, and the workflow that the patient should follow. The use of clinical guidelines is twofold: (a) to ensure the same medical treatments and cares for each patient and (b) to protect the medical doctors against any legal issue.

On the other hand, the quality indicators of the hospital depends of the effectiveness of the clinical guidelines that are used in the treatment of the patients. It is important that the application rate of the clinical guidelines (the patients that truly follows the guideline without any desviation) doesn't decrease, because of that the clinical guidelines should be continuously under revision to ensure the proper behavior of the system. But this is not the only factor to consider, cost and time requirements of treatments are also relevant for these indicators. This reason made the medical doctors to be more and more interested in the costs and resources needed in each part of their job (cost of necessary/unnecessary tests, alternatives with the same efficiency, etc.).

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New advances in technologies could be used in order to reduce time, cost and improve the use of treatments. In order to deal with these new technologies, clinical guidelines should be continuously updated. Furthermore, before introducing a new technology, it is very important to have a tool in order to evaluate its impact before the implementation. For that, in collaboration with the Hospital “Lozano Blesa” of Zaragoza, in order to monitor the efficiency and effectiveness of the clinical guidelines and to help their development and modification, we created *HEAT (Healthcare Efficiency and Effectiveness Analysis Tool)*.

This paper presents a software tool developed on the theoretical results presented in [2] and [3]. In particular, a domain specific modeling language -called Healthcare System Specification (HSS), defined as an Unified Modeling Language (UML) profile has been introduced in [3]. HSS extends UML activity diagrams in order to specify resources, workload and timing requirements in the health domain. Transformation patterns from HSS to Stochastic Well-Formed Nets (SWN) were also provided to obtain a formal model. The resulted formal model can be used for qualitative and quantitative analysis of the system by providing, for example, estimation for different performance indices to improve the efficiency and effectiveness of the system. This analysis can be performed by using Petri net specific tools such as GreatSPN [4] or TimeNet [5] directly called from HEAT.

HEAT is composed by two separate tools: one used to develop and analyze clinical guidelines and a second one to be used in the daily work at the hospital by tracing the patients treatment graphically. This second tool updates the statistics of the process (i.e., activities' time, statistics of decisions, etc.) to control the correct functionality of the current guidelines and looks for better solutions when necessary.

This paper is organized as follows: Section II, gives an overview of the related works and software solutions in health-care analysis and clinical guidelines. Section III introduces the HSS profile used to develop clinical guidelines and defines the formal definition of the Stochastic Well-formed Net (SWN) and introduces the facet of resource management and the facet of handshake between clinical guidelines used by this software. Section IV gives an overview of the main features of HEAT while in section V, a real use case is presented. Finally, in section VI some conclusions are given.

## II. RELATED WORK

Nowadays, there exist several software solutions for health-care modeling and analysis. Most of them are based on Busi-

ness Intelligence models and they provide analytics from big volumes of raw data and mainly focus on big systems, and on reducing costs of the system, e.g. Oracle Enterprise Healthcare Analytics [6] or Cognos from IBM [7]. These softwares have a lot of functionalities, but a specialized knowledge is needed to work with them. In this paper, we introduce a *simple software tool* to control the effectiveness and efficiency of the medical interventions and to control the use of resources based on clinical guidelines. Other software, such PROForma []

On the other hand, different modeling languages exist for clinical guidelines, e.g., guideline interchange format (GLIF) [8] or guideline elements model [9], for decision support systems. These models have friendly user interfaces for the doctors and can be used to simulate the system under different scenarios, but there is no possibility to formally analyze the system. Furthermore, there exist other proposed models [10] where the clinical guidelines are modeled by colored Petri nets. These are formal models that can be used for analysis but the models are more difficult to be understood by medical doctors.

The most frequently approach used for modeling complex information systems is business process modeling (BMP). Unified Modeling Language (UML) [11] is a standard language for this purpose. A business process model reflects the behavior of complex processes including involved participants, activities carried out by the formers and data flow generated by the process. In [12] it is proposed a system to model the clinical guidelines by UML standard using statecharts. The authors provide also a conversion algorithm to colored Petri nets.

The methodology used in HEAT is also based on UML [3]. It uses the HSS profile where new features are incorporated to the activity diagrams adding timing/stochastic information and use of resources in an easy way to be managed by medical doctors. Furthermore, this method uses rule-based transformations in order to obtain SWN models. Because the obtained colored Petri net can be very complex and the reachability graph impossible to be obtained, different *facets* of the system are defined that can be used to study particular properties.

### III. PRELIMINARY RESULTS

A clinical scenario is defined as a set of: (a) clinical guidelines, (b) available resources, (c) patients and (d) patient’s medical records. Applying the transformation rules in [3] to a clinical scenario, a SWN model of the system is obtained. This model permits to study the qualitative and quantitative properties of the system, such as the time that a patient needs to be hospitalized, the duration of the resources in use or to understand where are the bottlenecks of the system and how to solve them. The resulted colored net can be used to evaluate the performance of the clinical scenario with some external tools, GreatSPN [13] and TimeNET [5].

#### A. Healthcare System Specifications

The methodology proposed in [3] considers that a clinical guideline is described as a set of Activity Diagrams (AD), one for each disease and for each day of hospitalization. Each clinical guideline’s day includes a set of *care steps* that need to be carried out in a given temporal order. A care step represents a task to be performed by the personnel in charge of the patient that may require the usage of resources (e.g., the doctor) or patient’s health information (e.g., the patients’ allergies) to be carried out.

An AD of a clinical guideline mainly captures the control flow of activities (sequential execution, alternate paths) through the activity/control nodes and edges. There are different types of **activity nodes** as can be seen in fig. 1:

- **Initial node** (a) (shown as a solid circle) represents the beginning of a clinical guideline;
- **Action node** (b) (represented as rounded rectangles);
- **Choice node** (c) (represented as a diamond) models decision with alternate paths;
- **Merge node** (d) (also represented as a diamond) is used to unify alternate paths;
- **Final node** (e) (shown as a solid circle with a hollow circle inside) models the end of a clinical guideline.

This activity nodes are linked by **activity edges**, shown as *directed arrows* between two activity nodes.

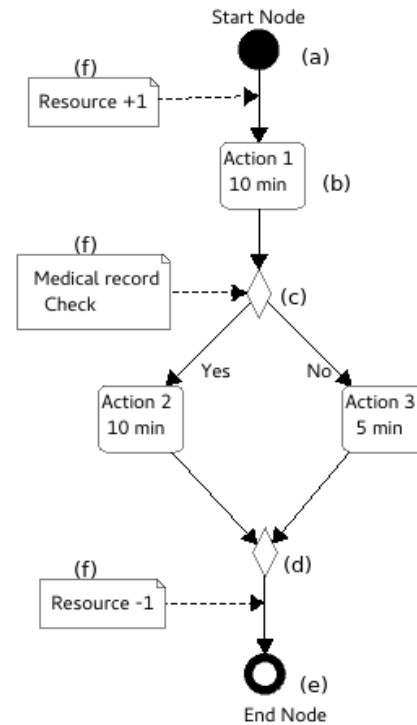


Fig. 1: A HSS example

The HSS profile add a new element with respect to the standard AD called *tags* (f), represented by a rectangle with a

bended edge, linked to diagram's components by a *dashline*. Those tags can specify just some annotations to an activity or give special properties to the linked component and/or the diagram (i.e., a tag added to an edge that comes from a choice could be used to specify probabilities to the decisions to be taken, while the tag added to the initial node could be used to specify the number of patients waiting for this treatment).

The *resource usage step* and *health info usage step* are particular types of care steps that can be used to allocate/release resources and send/receive/consult a message (or a medical record). These steps can be assigned to the edges. In the case of *resource usage step*, it is possible to specify the resource type (e.g., nurse) and the number of resources to be allocated -or released- for the next steps. In the case of *health info usage step*, added also as a tag to an edge, allows one to select an action to be performed on a given patient's medical record: create (add the patient to the list), useID (take a given patient from the list), use (take a patient form the list) and read (check if the patient is included in the auto-transfusion program).

### B. Stochastic Well-Formed Nets

HSS is a graphical language that helps on the development of clinical guidelines but can not be used to perform a formal analysis of the system. For that reason in [3] are described some local rules to transform the model described by HSS to an equivalent one using Stochastic Well-formed Nets (SWN).

A SWN [14] is a high level Petri net  $\mathcal{N} = \langle P, T, C, D, W^-, W^+, W^h, \Phi, \Pi, \Omega, M_0 \rangle$ , where  $P$  is the set of places,  $T$  is the set of transitions,  $C = \{C_1, \dots, C_n\}$  is the set of basic color classes. In our case we have one static color class  $dP$  for patients and one color class for each available resource in the clinical scenario.  $D$  is a function that associates a color domain to each place and transition of the net, expressed as Cartesian product of basic color classes. Tokens in a place  $p \in P$  incorporate information and it can be seen as instances of a data structure whose type is the color domain of  $p$ . In our context  $D$  has the information about the patient and the resources in use on each place.

$W^-, W^+, W^h$  are input, output and inhibitor arc functions. The classes in the color domain define the types associated with the transition parameters. Only transition instances can fire and their enabling and firing depend on the expression of the arcs connected to the transitions.

$\Phi$  is a function that associates to each transition  $t \in T$  a guard expression: guards are used to restrict the set of admissible color instances of a transition to those satisfying a given predicate. A predicate is a boolean expression and by default,  $\Phi(t) = true$  is assumed.

$\Pi$  is the priority function that assigns a priority level to each transition. Timed transitions are graphically represented by white tick boxes, and they are characterized by zero priority. Priority levels greater than zero are reserved, instead, for immediate transitions, graphically represented as black thin boxes.

$\Omega$  is a function that associates to each timed transition a (mean) firing rate, that is the parameter of the negative

exponential probability distribution function characterizing the random firing delay of the transition, and to each immediate transition a weight. Transition weights are used for the probabilistic resolution of conflicts among immediate transitions with the same priority. This weight is set on the decisions by the statistics obtained form history information from hospital to get a better approach to the reality and better results of the performance evaluation (e.g., Are there any infections? 90% No, 10% Yes).

Finally  $M_0$  is the initial marking function that assigns to each place either a multi-set over its color domain or a parameter. The initial marking parameter  $nP$  is set to the symbolic marking value  $\langle S \rangle$ , that corresponds to the formal sum  $\langle p_1 \rangle + \dots + \langle p_N \rangle$ . The place *guideline-start* initially contains  $N$  tokens, one per color in the color domain  $dP$  (i.e., one per patient requesting this treatment).

Applying the transformation rules in [3] to the example on Fig. 1 the resoulting SWN can be seen in Fig. 2. On this example a "Resource" is allocated at the begining of the clinical guidelines and released after the merge point. Each activity is translated into a timed transition and the decision point checks the "Medical record". In the positive case that the patient is included in this medical record, the information is readed from the medical record place and introduced again. If the patient is not included, by the inhibitor arc, the clinical guideline continues to the place  $p13$ .

**Abstraction into facets.** The analysis of a Colored Petri Net has, in general, a very big computational costs due to the enormous size of the state space. To cope with this problem, the model can be seen as *multi-facets*, defining a facet for a different perspective of the system [3]. Many structural results exist in PN literature. For example deadlock prevention has been extensively studied in Resource Allocation Systems [15] and can be used when the resource management facet is considered. For the communication between clinical guidelines facet, some results exist for liveness characterization in DSSP [16] and [17].

## IV. TOOL DESCRIPTION

*HealthCare Efficiency and Effectiveness Analysis Tool (HEAT)* [18] is a software designed to provide to the hospitals a tool to analyze the efficiency and effectiveness of their systems. It was designed to be used by the hospital personnel, and assumes that the final user my not be familiarized with the use of new technologies or tools. Because of that, the resulting software should be equipped with a friendly user interface. HEAT is a multi-platform software developed with Qt and MySQL. Qt is a cross-platform framework for developing graphical user interfaces that can be run on various hardware platforms. MySQL is an open-source relational database management system that can be run also on different software and hardware platforms. It is widely used for web applications and can be useful in future upgrades.

HEAT provides a tool to develop clinical scenarios in order to control the correct resource usage, the required time of each resource, to see if clinical guidelines are followed up correctly

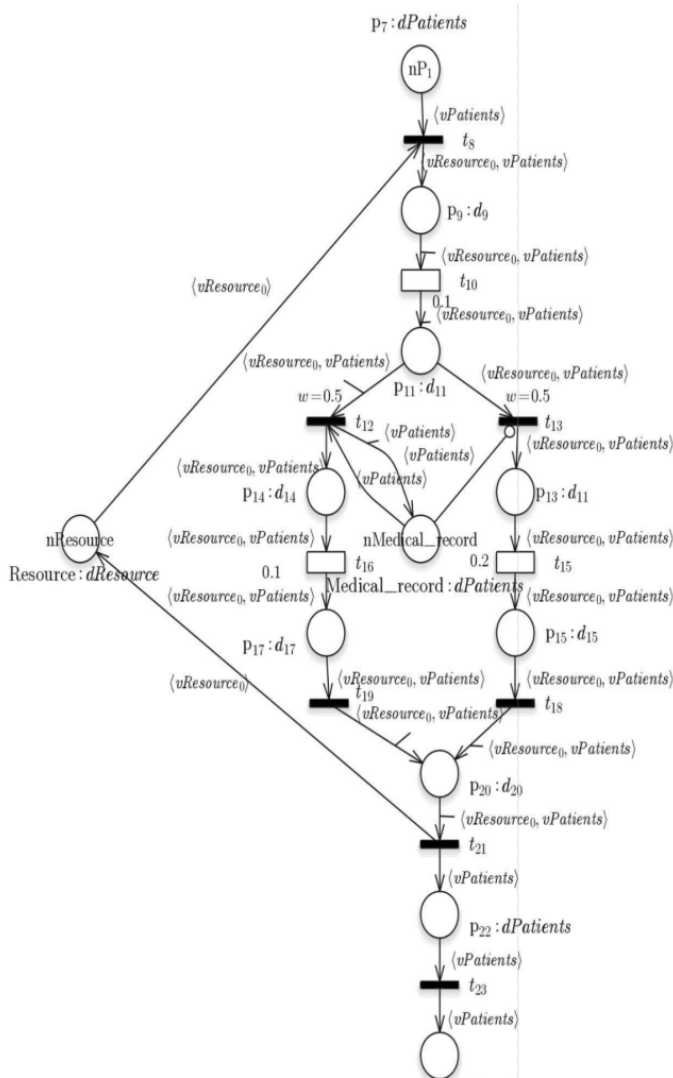


Fig. 2: Result of the transformation of the example on Fig.1 to SWN

and if the clinical guidelines and the system work properly or if it is necessary to improve them. All these information will help the decision maker to reduce the costs and the time of the patient's treatments, to avoid useless resources and to plan better schedulers to minimize the queue of patients on the waiting list.

This section is an overview about the main features of *HEAT*. It is composed of two programs *HEAT Scenario Designer* and *HEAT Patients Monitor*.

#### A. *HEAT - Scenario Designer*

It has been created to allow the medical experts to create or update the clinical guidelines. Moreover, it allows the decision maker to administrate the clinical scenarios. A clinical scenario is composed by a set of clinical guidelines, hospital's available resources, medical staff and the relevant patients' health information (i.e., medical records) for the clinical guidelines. In this paper we consider the Orthopedic Surgery scenario

corresponding to the orthopedic department of the Zaragoza's University Clinical Hospital "Lozano Blesa".

The Graphical User Interface (GUI) of this tool (Fig.3), provides (a) a menu bar with three drop-down menus: (i) *Escenario* (English: clinical scenario), (ii) *Administrar* (English: Settings) and (iii) *Vías clínicas* (English: Clinical guidelines); (b) a tool bar, (c) properties area and (d) design area.

The *Scenario* menu, allows to select one of the available clinical scenarios, create new scenarios, modify some basic properties of an existing one, delete them and transform, by the *transformation tool* described below, a clinical scenario and the clinical guidelines in order to be analyzed.

Once a clinical Scenario is selected, the second menu *Settings* becomes selectable allowing to configure the selected scenario by the four submenus found in it. (i) *Doctors'* submenu permits to configure the medical staff working on each clinical scenario. (ii) *Resources'* submenu allows to add/modify/delete the available resources in the system. Medical records are the relevant patient's information used by the clinical guidelines in order to set the steps to follow and make a good decisions to each patient (e.g., Is the patient included in the "Auto Transfusion" program?) and can be edit by the (iii) *Medical Records'* submenu. The last submenu, (iv) *Clinical Guidelines*, lets to select the clinical guidelines used for the medication of the diferent patologies treated on the selected clinical scenario.

The third menu on the menu bar, also called *Clinical guidelines*, allows to create a new clinical guideline, save the current clinical guideline in the database and open/delete an existing one from the database. Also allows to import/export the clinical guidelines in/from a xml file.

The development of CGLs is the main feature of this program. As defined in Section III-A, a clinical guideline is composed by a set of activity diagrams, one for each day of hospitalization. On the other hand, an activity diagram is a set of linked steps to be followed in a specific order helping the doctors on the decision-making for a specific medical condition. Furthermore, this activity diagrams include the use of resources needed on each step.

The diagrams are developed in the *Design area* with a friendly interface, where UML-HSS' specifications knowledge is needless. A new diagram starts with the initial node, and from is the next diagram's componet can be easily added by a pop-up menu. On the top of this area there are a set of tabs to select the day of the guideline to be developed.

On the *toolbar* we find the buttons "+" and "-", to add and remove respectively the guideline's days and some other usefull tools, i.e., zoom of the Design area and export button.

The *properties area* shows the properties for the selected item of the diagram. This area, divided into three parts, allows us to introduce the diferent elements of the HSS. On the top (i) a text area allows to introduce the description of each activity of the clinical guideline. The area in the middle (ii) contains a menu used to allocate and/or release resources and the diferent actions to perform with the medical records. On bottom (iii), there is a table with all the properties of the selected item.

Using it we can modify other features of the diagram, such as task's average timing or the probability on a decision to be made.

1) **Transformation tool:** Once the clinical scenario is introduced we can transform it into a formal model. Depending on the property to be analyzed we can obtain a SWN that models all the details of the scenario, but also P/T net models can be obtained. By decoloring the SWN and by eliminating the communication nodes between clinical guidelines, the so called *Resource's management facet* [3] is obtained. The use of this facet is described in more details in section V. In this transformation, each day of a CGL is analyzed texting if there exists incongruences in the use of assets: ensure that no more than the available resources are requested, by controlling on each step that the allocated resources do not exceed the available; and all of them are released at the end of the day. If there is no inconsistency, the transformation is executed and the resulting net is exported to different formats to be analyzed by different tools (i.e., GreatSPN's PNPRO file format and TimeNet's xml format). A second P/T net model can be also generated by decoloring the SWN and, in this case, by eliminating the resources places, obtaining the *facet of handshake between clinical guidelines*. Nonetheless, the study performed on the simulation is focused in the *Resource's management facet*.

### B. HEAT - Patients Monitor

This second tool of *HEAT* will be used by medical doctors on the daily work. With this second tool, the doctors can manage the patients and their information (e.g., clinical history number, name, doctor in charge of the patient, patient's health information -Medical Records- and diseases). As well as monitoring the activities carried out for the treatment.

It has a similar GUI as the previous one (see Figure 4) with some differences. In the menu bar of *HEAT - Patients Monitor*, there is only the *scenario* menu used to select a clinical scenario. The *tool bar* contains the buttons to introduce new patients and delete them as well as the three lists to select the patient to be monitored. The first list (a) is to select which patients can be selected: (i) patients with activities to be carried out during the current day, (ii) hospitalized patients and (iii) all the historical patients; the second list (b) is to select the patient to be monitored and the third list (c) is to select the clinical guideline to display in case of being used more than one.

The main area shows the guideline for the disease of the selected patient. On it the current activity is shown in green while the already performed activities are shown in yellow. The result of every decision and the time required on each activity are used to update the statistics (probability of a decision to be done/average time of an activity), in order to get a faithfully result on the analysis.

The properties area of *HEAT-Patients Monitor* is also divided in three parts. On the top (i) is shown the information on the current patient and the day of treatment to be followed. In the middle (ii) there are two text areas: the first one (a)

shows the description of the selected activity and the second (b) allows to introduce some relevant reports or commentaries about the patient treatment. Comments that will be shown on the diagram as yellow tags linked to the corresponding item.

The usage of it is the same, but this time the pop-up menu allows to set the activity as done and, in case of choice, to select the next task to be carried out.

## V. SIMULATION EXAMPLES

In this section is developed a simulation in order to show the results of the transformation obtained from the clinical guideline developed using the HSS profile and some analysis that can be computed to the resulting SWN model as well as the advantages of using the Facets to simplify some analysis of the model.

As a case study, the *hip arthroplasty* guideline used in the Hospital "Lozano Blesa" of Zaragoza is considered. The clinical guideline and the resulting transformation can be found in the web page of the project [18]. This clinical guideline is composed by 7 days of treatment (i.e. pre surgery day, surgery day and 5 post surgery days). The required resources are *Doctors, Nurses and Assistants* and the relevant medical records for this treatment is the inclusion of the patient in the *Auto Transfusion Program* (i.e. for the surgery of this patients included on this medical record is used their own blood drawn some weeks before). In the simulations, the times introduced for each task were approximated values provided by medical doctors because there are no records on the average time for each activity.

For the analysis, two different tools namely TimeNET and GreatSPN were used. TimeNET is used for an analysis by simulation, providing an efficient approach for big nets. GreatSPN is used for precise solution by a Markov Chain analysis, used to get reliable values.

The Fig. 5 shows how the model is represented as paralel guidelines corresponding with the diferent clinical guidelines days where the same number of patients are introduced in each guideline. This forces to treat the same number of patients in all the days, narrowed by the bottle neck day.

The original model of the guideline had more than 500 nodes (places and transitions) and some reduction rules have been applied. In particular, a sequence of activities performed by using the same resources is reduced to only one transition, reducing considerably the size of the model to 297 nodes and 4 color classes (Patient, Doctor, Nurse and Assistant). Checking the model by an Reacheability based analysis can be probe that the model do not have dead markings out of the set of final places of each clinical guideline, i.e., the patients finished the treatment correctly, but the analysis of a SWN requires high computational cost and the size of the Petri net makes unfeasible the use of this method to analyze the guideline. The table.6 shows the number of states and the time required to compute them depending of the included patients. The time to compute the graph increases exponentially as well as the memory required because of the number of reachable

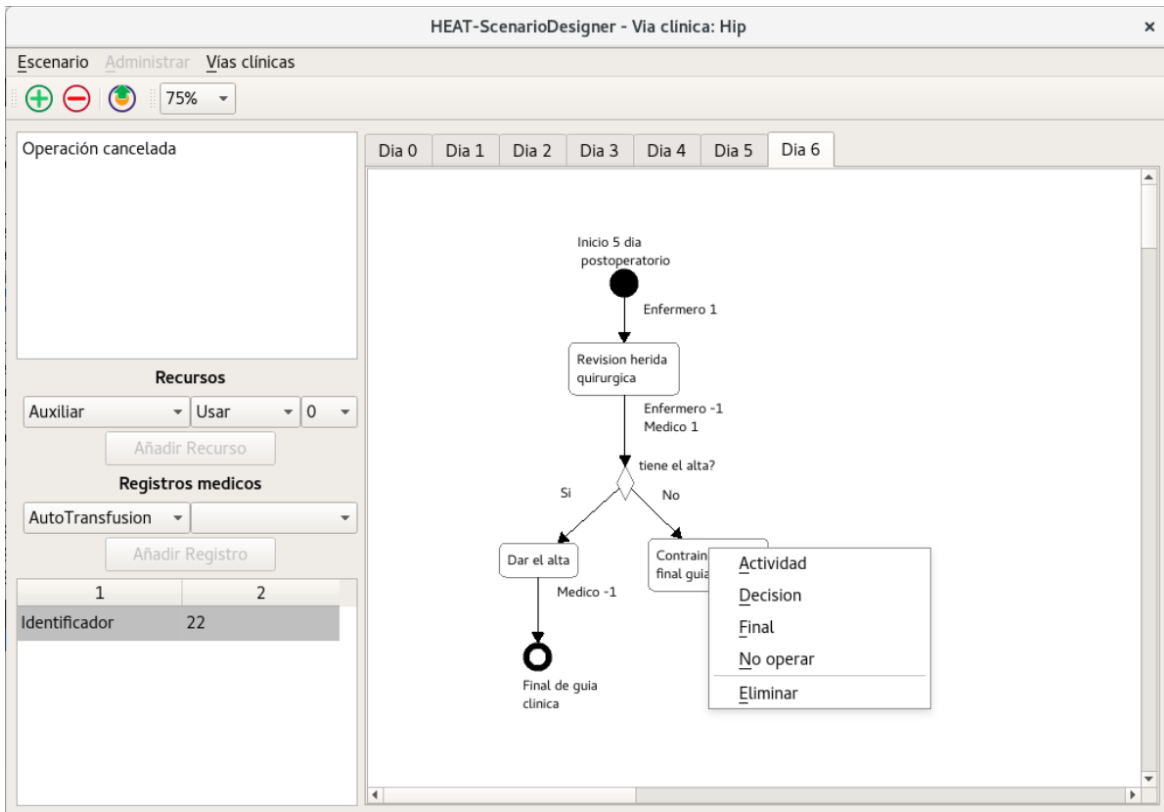


Fig. 3: HEAT - Scenario Designer: (a) Menu bar, (b) tool bar, (c) Propierties area and (d) design area.

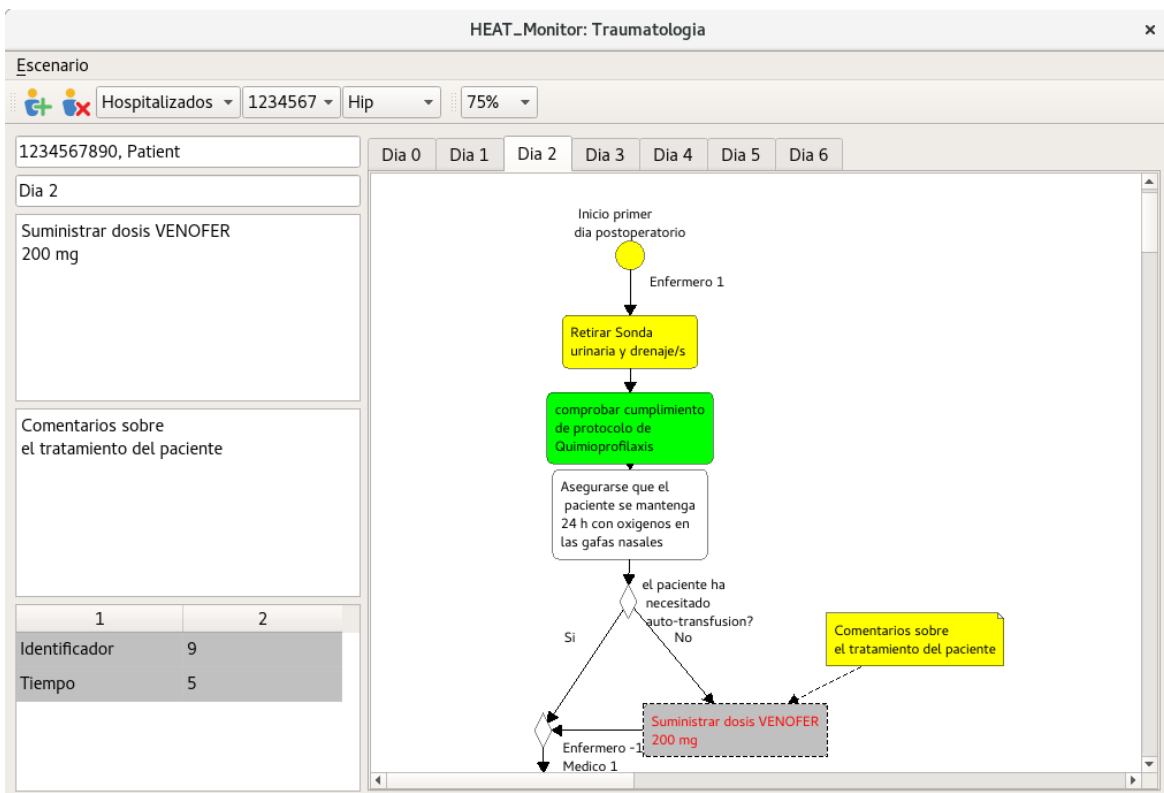


Fig. 4: HEAT - Patients Monitor

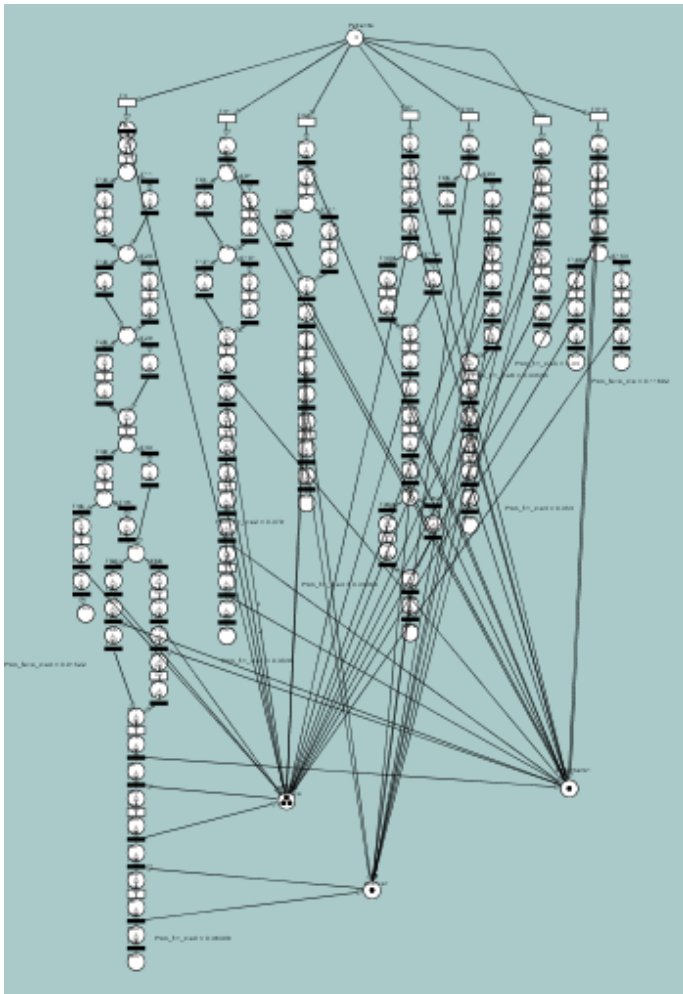


Fig. 5: The SWN model of the hip arthroplasty guideline.

markings. Just the day 0 needs more than 3 hours to solve it, having computed more than > 400000 markings.

Patients	Day 0	t	Day 1	t	Day 2	t	Day 3	t	Day 4	t	Day 5	t	Day 6	t
1	87	1	34	1	16	1	20	1	18	1	11	1	21	1
2	21013	8	517	2	183	1	544	2	215	1	93	1	297	2
3	92917	60	9696	5	1611	3	6962	5	1909	3	577	2	2947	4
4	400000	4180	33849	12	14415	6	76910	23	15545	33119	2	25433	5	

Fig. 6: Results of a reachability based analysis of the days with 3 Doctors, 1 Nurse and 1 Assistant. (Number of reachable Markings; Computational Time)

For an structural analysis of the model, in order to probe that the model is conservative and consistent, it is transformed into a strongly connected net by adding an immediate transition from the last place of each clinical guideline to the initial place. From this model can be computed the P and T-semiflows. The semiflows are left and right annular of the incidence matrix, hence structural elements. Moreover, they are related to some properties of the system, in particular P-semiflows corresponding to token conservation laws (in our case the resource conservation laws) while T-semiflows correspond to repetitive behaviors (any path of the patient that

return to the population place should correspond to a repetitive behavior). A net is conservative if all places belong to at least one P-semiflow and consistent if all transitions belong to one T-semiflow. In this case is proved that all places are covered by P-semiflows and all transitions are covered by T-semiflows.

Once the correctness of the model is verified some performance measures are evaluated. On this simulation we are computing the maximal number of patients that can be treated on a working day of 8 hours (480 min). For that is computed a transient analysis to see the number of patients that can be treated after this time by the available resources, which, as mentioned before, are the minimal required for this clinical guideline. First this analysis is computed separately for each clinical guideline day to see which is the day that narrows the system, i.e., the bottleneck, and this result gives the maximal throughput of patients a day that can be treated by this resources. This analysis was computed on the SWN model and on the *Resource's management facet* model with the results in the tables Table.7 and Table.8. As can be seen the use of the Resource's management facet, simplifies the analysis obtaining the same result when we analyze the number of patients that can be treated in a given time by a set of configured resources reducing a lot the computational cost.

With in the obtained results can be seen that for all the average token count on the last place of the guideline equal to the number of patients to be treated, but on the case of the Day 1, i.e., the surgery day, although the number of patients to be treated increases, the number of patients that can end the day can not be more than 3 a day.

When we proceeded to analyse the complete model of the guideline by the transient analysis, if we use the colored model for one patient the required time to compute it was 1028 with one patient, that makes unfeasible to use this model to continue with the analysis because of that, the resource's management facet was used for the next simulation.

In the Table. 9 we can see the results of the transient analysis in the complete clinical guideline considering 4 patients. If more patients as possible are introduced the system collapses reaching to operate just 2 of them. Is important to receive just the patients that the resources allows.

## VI. CONCLUSIONS

In this paper we propose a tool for the development of clinical guidelines. We have seen that the clinical guidelines are important in medicine, and that they are getting more and more leadership in a society where providing the best healthcare with the correct allocation of the resources is priority one.

We create as primary objective a software application to support the designing and analysis processes of clinical guidelines. This software is called Healthcare Efficiency and Effectiveness Analysis Tool (HEAT) and is composed by two separate tools: one used to develop and analysis of clinical guidelines and another one to be used in the daily work at the hospital by tracing the patients treatment graphically. The methodology used in this software is based on UML (Unified

Patients	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
1	0 / 0,9974	0 / 0,9794	0 / 1	0 / 1	0 / 1	0 / 1	0 / 1
2	9 / 1,9949	1 / 1,8781	1 / 2	1 / 2	0 / 2	0 / 2	1 / 2
3	309 / 2,9925	18 / 2,6188	4 / 3	24 / 3	6 / 3	2 / 3	8 / 3
4	ERROR	236 / 3,1545	52 / 4	423 / 4	88 / 4	13 / 4	118 / 4
5			2530 / 3,49				

Fig. 7: Average token count on the last place of each clinical guideline day, i.e., mean number of patients that can be treated in a working day computed on the SWN model (Time in seconds / Value).

Patients	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
1	0 / 1	0 / 0,9794	0 / 1	0 / 1	0 / 1	0 / 1	0 / 1
2	1 / 1,9947	0 / 1,878	0 / 2	0 / 2	0 / 2	0 / 2	0 / 2
3	10 / 2,9925	0 / 2,6188	0 / 3	1 / 3	1 / 3	0 / 3	0 / 3
4	65 / 3,995	2 / 3,1545	1 / 4	3 / 4	1 / 4	0 / 4	0 / 4
5			6 / 3,49				

Fig. 8: Average token count on the last place of each clinical guideline day, i.e., mean number of patients that can be treated in a working day computed on the *Resource's management facet* model (Time in seconds / value).

	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Prob.	0.85	0.21	0.97	0.97	0.99	0.98	0.39
Average.	3.78	2.23	3.95	3.93	03.99	3.96	2.21

Fig. 9: Result of the transient simulation with 4 patients.

Modeling Language). We provide also an implementation of a conversion algorithm to colored Petri Nets. Since the analysis of a Colored Petri Net has, in general, a very big computational cost, due to the enormous size of the state space, the model can be seen as multi-facets, defining a facet for a different perspective of the system. On this first version of HEAT we have analyzed the facet of the resource management.

In conclusion, HEAT allows the best possible administration of clinical scenarios, has a user-friendly interface, making it easy to use by medical personnel, and is interactive at the same time, permitting to add/modify/analyze clinical scenarios.

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