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A Conceptual Representation of Clinical and Managerial Guidelines: The ATREUS Workflow Model

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Abstract

In this paper we propose a workflow conceptual model able to represent clinical and managerial activities within healthcare structures, the ATREUS model.

This model uses: a) a graphical representation which models the activities and the events that activate them; b) a textual representation of information related to: a set of conditions used for the control of activity execution; the actors who undertake the activity; the resources and tools necessary for its enactment, the clinical and managerial data generated by the activity execution; c) a state diagram which allows the control of the activity execution.

The model allows modularity, activity nesting and temporal flexibility using a top-down refinement of processes. This model, unlike others, makes it possible to highlight the different types of decision involved in the performance of an activity.

Keywords

Workflow; Collaborative work; Guidelines; ATREUS model

1. Introduction

In the process of hospital re-engineering two key concepts are fundamental in order to contain healthcare costs and improve the quality of treatment: continuity of healthcare and co-operation between healthcare units (HCU). In fact in modern healthcare systems the provision of treatment for a single occurrence of disease is based on interaction between different operators which is not strictly pre-defined. Moreover, those operators possess different skills and a high level of autonomy, since they belong to different HCUs. This implies an integrated view of [1]:

- clinical activities (therapeutic, diagnostic, nursing) necessary to provide patient care in which several healthcare structures participate;
- managerial activities necessary to perform a single clinical activity;
- activities which permit communication between two HCUs and provide the basis for co-operation.

By Guideline (GL) we mean "a structured, flexible and coherent specification of a set of actions triggered by a problem or task and performed by agents with different specialised skills" [2].

In business re-engineering systems the sets of activities (and therefore the GLs) are described through a high level language, or through a graphic representation (Conceptual model of WorkFlow). By means of the conceptual representation of the Workflow (WF), we can describe the patient treatment process at different levels of detail in order to [3]:

- describe both clinical and decision-making aspects;
- create a workplan for physicians and nurses;
- synchronise the different clinical and managerial activities performed on a single patient;
- co-ordinate the information exchange between the different operators (physicians, nurses, etc.), who deal with a single patient;
- verify at opportune time the state of execution of the different activities performed on a specific patient.

The ATREUS model supplies a representation of information connected with a WF at graphic and textual level. In order to describe the interaction of different activities (clinical and managerial activities), this model represents both the human collaboration and the repetitive administration processes. The former describe the process of treatment of a patient carried out by a physician, the latter describe all the administrative and managerial aspects involved in the process of treatment. Following the classification prosed in [4], the ATREUS model is able to represent both the *administrative WFs* and *ad hoc WFs.*

2. The Atreus Model

The ATREUS model is based on the three representations (complementary among themselves) [5]:

- The *graphic representation* describes the activities and the events that activate them. According to a top-down development it permits to represent the component activities of a complex activity.
- The *textual representation* describes the data of the activity. An example of textual representation for an activity is represented by its identifier, a set of condi-

tions used for the control of the beginning, the execution and the conclusion of the activity itself. This representation also provides further information, such as the actors who undertake the activity, the resources and tools necessary for its enactment, the clinical and managerial data generated by its execution, etc. This information is necessary for the evaluation of the organisation process and resources (material, human and informational) involved in the WF.

- The *representation of the activity execution* describes the functioning of the WF. It identifies the set of possible states of each activity, and controls the activity execution. This part also foresees the exception handling in order to represent activities which have a unsuccessful conclusion.

2.1 The ATREUS model: graphic representation

The ATREUS model is based on the concept of hypergraph [5]. Here we give an example of the model. Figure 1 describes the process of healthcare provision in a hospital ward. As soon as a patient enters a hospital ward, she/he is taken in charge by a nurse (who assigns him/her a bed and carries out a first interview), then a physician makes a first examination to derive the anamnesis and to define a treatment plan (*clinical-diagnostic activity*). The treatment process is based on three activities which run parallel: *therapeutic activity, the collection of clinical parameters* (e.g.: temperature, blood pressure, etc.) and *diagnostic activity* (e.g.: blood tests, X-rays, etc.). Every morning another examination is performed (*routine clinical examination*) in order either to: re-define the clinical-diagnostic activity or to transfer the patient to another ward or to discharge him/her. During the *diagnostic activity* and the *collection of clinical parameters* an unexpected event may occur (event: *emergency signal arrives*). This implies an *unforeseen monitoring* activity and consequently an *urgent examination* takes place. During this monitoring activity the patient may unexpectedly die (event: *patient decease*). As in the case of a routine clinical examination, the urgent examination may cause either the re-definition of the clinical-diagnostic activities or the patient's transfer to another ward. Therefore the delivery of the treatment ends either with the patient's dismissal or with his/her transfer to another ward, or with his/her death.

Although the graphical representation given in fig. 1 is a high level description, it shows some of the main characteristics of the ATREUS model.

The start of the process (event: the patient enters a hospital ward) and the end (alternative events: hospital discharge and patient transfer) are represented by the structural nodes of *begin* and *stop*.

Each activity node represents a complex or an elementary activity. In the case of a complex activity the node can be broken down into nodes that represent the component activities. The complex activities are represented by hypernodes. The activity node has 1 or more inputs and 1 or more outputs. It is represented by a rectangle containing the name of the activity. In the ATREUS model the primitive elements for the representation of activities are: sequence, parallelism, non deterministic sequence, multitasking, iteration [5].

Events are represented by labels on edges. Depending on the event resulting from the conclusion of a activity, it is possible to activate either an alternative path (alternative activities) or parallel activities. An example of sequence (i.e. totally ordered set of the n activities) is the node *nurse takes charge of patient*, which precedes the *anamnesis and physician's objective examination* node.

Examples of parallelism (i.e. activities that may be activated simultaneously and must be carried out at the same time) are the nodes *clinical-diagnostic activity*. It should be noted that it is also possible to describe graphically nested activities: the daily activities (*collection of clinical parameters* and *therapeutic activity*) which constitute the components of the diagnostic activity. Both component activities run parallel with the *diagnostic activity*.

The ATREUS model makes it possible to describe iteration, i.e. activities that are repeated several times until a previously established condition is reached. An example of this is given in fig. 1 in the node *collection of clinical parameters* which takes place several times a day.

In the WF shown in fig. 1, all the k activities which comprise the clinical-diagnostic activity have to be concluded in order to activate the subsequent activities. This is represented by K and *ALL*, where k is the number of activities that must be activated. The value k may be a single value, or a range (if the minimum value is 0, none of the activities must be activated and the next activity in the sequence is triggered).

The ATREUS model also makes it possible to represent activities to be carried out when unexpected though foreseeable events occur. This is possible either by the management of additional activities or by the suspension of activities already planned. In Fig. 1 an emergency signal generates an unexpected situation represented by the alternative path that leads to the node *urgent examination*. This event causes the conclusion of all the activities which compose the clinical diagnostic activity and activates the *urgent examination* node. When the latter is over, either the normal path is resumed or the patient dies. Totally unexpected events imply, on the other hand, the partial re-writing of a WF (see §3).

Based on the analysis of the example in fig. 1, the ATREUS model displays the following features [5]:

- Activity interaction - The primitive elements of the model manage different kinds of situation occurring during the execution of a process: concurrent activities, iterations, suspensions, exception handling, etc.
- Delegation - The model allows users to understand not only the task to be performed, but also how to assign tasks to operators and what resources are necessary to execute activities. This is possible by the textual description associated to each activity.
- User orientation - The user is provided with a graphical representation of the process, which should match her/his perception of it; thus, it is technology-free.

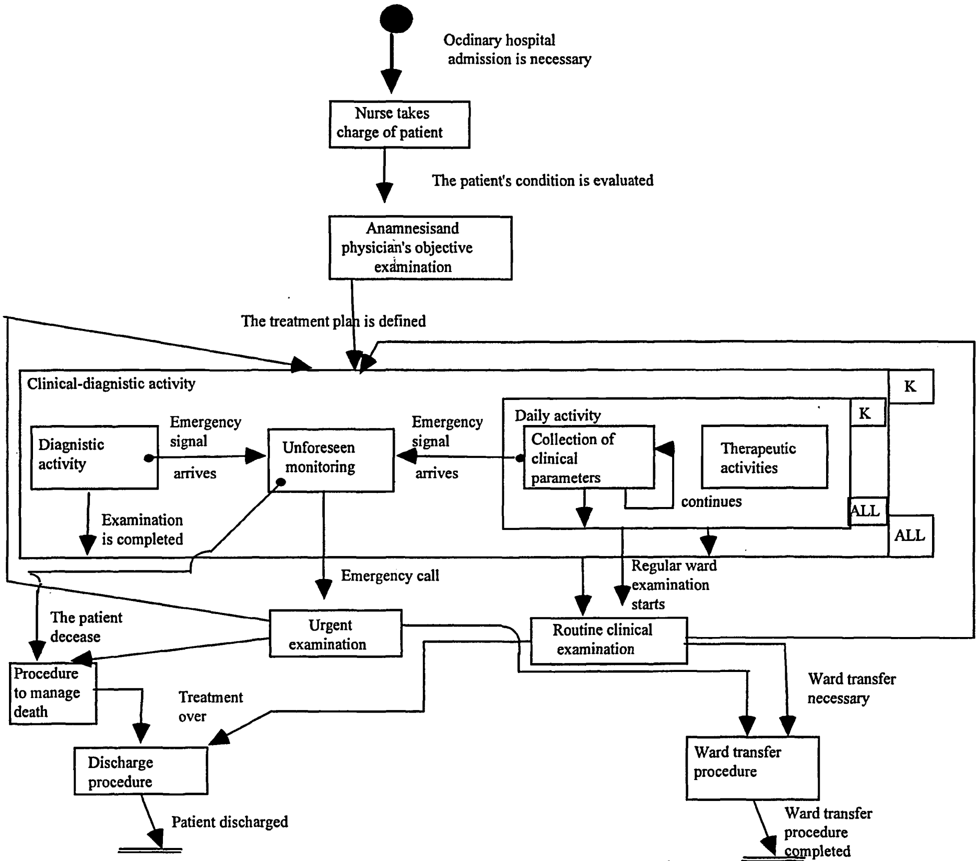

Figure 1 - An example of ATREUS scheme

- Monitoring of process execution - The user has a model such that it helps him/her to understand the whole process and in particular what has happened and what may happen next.

2.2 The ATREUS model: condition information

The representation of a WF involves the knowledge of a set of conditions that allow for the control of activity execution of the entire WF.

The ATREUS model manages the following conditions [5]:

- Pre-conditions - The "activated" conditions, in particular a) the conditions necessary in order to confirm that the pre-selected activity is the right one to activate; b) the condition that must be fulfilled in order to start the activity.
- Post-conditions - The criteria which state the successful completion of the activity undertaken.
- Constraints- the conditions that must be fulfilled by a set of activities during their execution. (e.g. the temporal relations between activities).
- Exceptions - The conditions which must be fulfilled in order to change the execution of the current activity, (e.g., by interrupting it and subsequently resuming it normally). The ATREUS model manages the exceptions using the state diagram. The states which express exceptions are the following: suspended, aborted, cancelled, re-assigned.

3. ATEUS's Design Methodology

In the definition of the WF it is useful to have a top-down development of the process. Starting from the WF to be described, this is broken down into its activity/WF components. The process is repeated until the level of granularity of the component activities is considered to be adequate. The ATREUS model makes different kinds of top-down development possible. We are illustrating the simplest kind: the substitution of a complex node by its development graph, considering the node's input and output events as simple.

This type of top-down development makes it possible to:

- model the process through a very generic WF scheme (WF template)
- maintain a library for each activity of the WF template which contains all possibilities of top-down development. Each instance of this library is described by attributes which characterize each instance and therefore

allow the choice of the most appropriate top-down development.

As an example we consider the case of rectal cancer following the indications of the National Cancer Institute (CancerNet). The WF template which describes the generic treatment of an oncological patient is shown in fig. 2

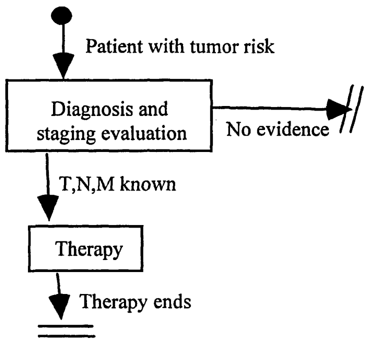

Figure 2 - An example of WF template

The choice of the therapy development depends on the rectal cancer stage. The attributes describing the instances of the WF library are: T (primary tumor), N (regional lymph nodes), M (distant metastasis). For stage I° (T=1 or 2, N=0, M=0) the development is shown in fig. 3: tumor is limited to bowel wall (mucosa, muscularis mucosae, submucosa, and muscularis propria). We need only one therapy procedure (conditional parallelism with K=1 for the more complex activity). The choice of single therapy procedure depends on the input event; for example, if the dimension of primary tumor is bigger than 4 cm. and the distance from the sphincter is equal to 3-4 cm. (input event=e1), low anterior resection (LAR) is performed. If the patient has high surgery risk and low life expectancy (input event=e6), local transanal resection is performed with or without perioperative external-beam irradiation plus 5 fluorouracil (5-FU) chemotherapy.

If we have a different rectal cancer stage (for example stage II°, with T=3 or 4, N=0, M=0: tumor has spread to extramural tissue), we have a different therapy development (an other instance of WF library).

The top-down development and therefore the use of the WF template related to the WF library allow [5]:

- Modularity - the description of the WF is modular; the instances of the WF library are re-usable; different authors can collaborate on a WF library; there can be different variations of the same WF, one instance for each variation.
- Nesting flexibility - the representation of an activity can expand into the representation of its component activities without nesting limits. There are no activities which are defined *a priori*. All activities can be further dismantled, the level of detail depends on the WF library which can be added at any time.

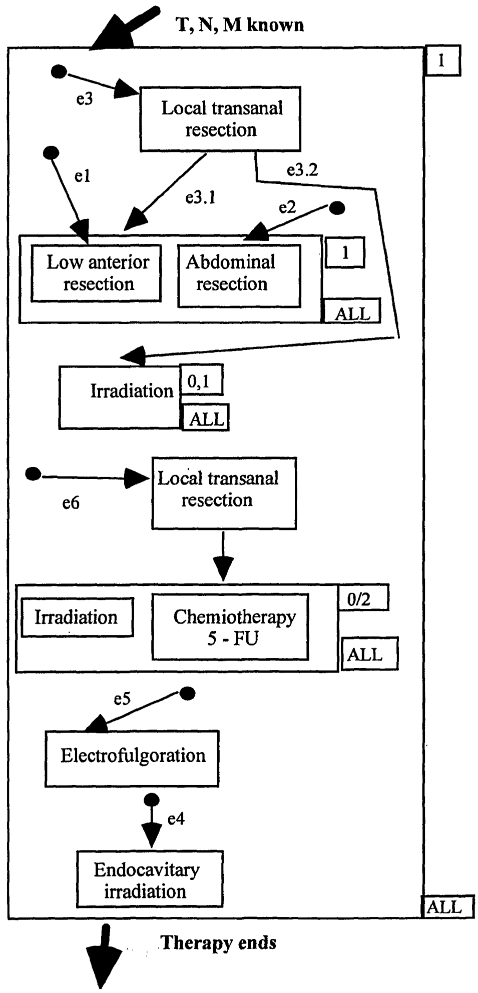

Figure 3 - ATREUS model of Stage I rectal cancer

- Temporal flexibility - the representation of an activity must be time-flexible, that is, the choice of the appropriate instance of the WF library to carry out a top-down development, is made when data are available and is modified according to the effects of the clinical treatment on the patient. In fact it is not possible to foresee all the details of a course of action from the beginning, but only a strategy which is progressively refined, avoiding premature restrictions. This makes it possible to describe the activities to be performed in unexpected situations using an instance in the WF library which is built ad hoc when such a situation occurs.

5. Discussion

The ATREUS model describes healthcare WF underlining the various types of decision-making involved [2]:

- Clinical strategy (what needs to be done for a single patient) - The clinical strategy destined for a single patient is the key note of hospital activity, which also involves organisational, economic and administrative aspects. The entire information system needs to be developed around this strategy [1], above all the aspects concerning management, at both ward and hospital levels. The analysis of the strategies adopted makes it possible to construct indicators of quality.
- Organisational and managerial strategy (who performs an action and when) - i.e. putting a clinical decision into practice via different steps (e.g.: taking a blood sample, preparation of sample, radiological exam, clinical report), which can be performed by different operators. In this case both information and material exchanges have to be considered as well as aspects connected to resources and the synchronisation of component activities [3]. This makes it possible to construct indicators of efficiency.
- Executive aspects (how to do technically) - i.e. "mechanical" step to be performed within the same HCU (by a single operator or by many operators who collaborate in order to reach the same specific aim), related to a clinical decision [3]. This makes it possible to construct indicators of efficiency.
- Administrative aspects - i.e. authorisations, accounting, bureaucracy; they constitute an important aspect of the information system, flanking activities and processes [3].

The description of clinical and managerial guidelines using the ATREUS model makes it possible to represent aspects which are not found in other models available in literature [6]. For example PRESTIGE (Guidelines for healthcare: faster implementation of healthcare standards) does not take independent protocols into account, while PROCAS (PROfile of CAre System) does not consider agents, resources and the communication between operators.

6. Conclusions

The ATREUS model permits to describe at a conceptual level the clinical and managerial processes carried out in a hospital environment. The feature of the ATREUS model fulfil the requirements of hospital WFs. The top-down approach of the ATREUS model allows the user to develop the WF detailing the description in such a way that he/she can identify step by step the activities to be performed and/or monitored. A prototype of WF management system based on the ATREUS model is going to be developed on Macintosh environment.

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