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# A UML Based Approach for "Patient Pathway" Modeling

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## ABSTRACT

In the last years, Italian Health systems have been redesigned considering patient as the centre of processes instead of the clinical event. So Ministry of Health has introduced the concept of "patient pathway" which describes the best sequence of medical actions to provide to a patient with particular diagnosis in the different hospital or non hospital structures. The design and representation of a "patient pathway" is a complex process involving different actors so it needs a systematic work with periodical reviews to take into account the obtained results or the influences deriving from the external environment. In this paper we present a model for the definition of such "patient pathway". The model is based on a UML extension. With this extension we have introduced in UML some typical elements of health domain and other elements deriving from management, such as the elements related to "Activity based costing". This approach allows to represent exhaustively the entire health process, gathering the health costs related concepts and providing, thanks to UML, a support for developing applications related to these health processes.

## INTRODUCTION

In the last years we have seen a radical transformation in the world demographic scenery. The number of old people is increased, so epidemiologic scenery has changed too, because chronically diseases take place of acute diseases.

In Italy, the number of citizens with one ore more chronically disease is near to 30,3% of the population [2]. Within the people older than 66, 17% is affected by permanent disability.

In order to give an answer to the increasing request of health treatments, National Health Service has been redesigned, moving the place of care and treatment from the hospital to territorial structures and from these structure to patient home. It has been possible thanks to the "sensitiveness" of the "actors" operating in health system and to the new opportunities provided by scientific research in diagnostic and therapeutic field.

Health Ministry, illustrating the 2002 health research program, explains the following: *"the dispersion of resources and the difficulties to grant the access and the welfare continuity. This is made more critical by the dishomogeneity of operative context, by the effective availability of resources, technologies, know how".*

Ministry defines the following solutions: *In many of these cases it could be useful to realize, using adequate tools and methods, an analysis of healthcare process to design those which are more suitable. This means to define the concept of "patient pathway" (the Italian "profili di assistenza"), which is an interdisciplinary program created to satisfy specific clinical problems, and which aims to reduce the inappropriate clinical treatment and the related unnecessary costs. It defines the best sequence of treatments addressed to patients with particular diagnosis and conditions within the different kind of hospital and non hospital services. In this sense the "patient pathway" could be an important tool supporting the continuous improvement of the clinical practice, with significative results on patient outcomes and on the system efficiency.*

The design and representation of a "patient pathway" is a complex process which involves many actors and needs for a systematic work, time developing and continuously checked to take into account the obtained results or the possible influences of the external environment.

Consequently, it is necessary to make some choices as the following:

1. considering patient as the centre of the system rather than the provided treatment;
2. working in pool with other professionals who, even operating in different structure, follow the evolution of the disease;
3. formulating educational programs aimed to acquire the best scientific evidence;
4. defining the profile and realizing this profile

In this paper we present a model for the definition of such "Patient pathway". The model is based on an UML extension. By this extension we have introduced in UML some typical elements of health domain and other elements deriving from management, such as the elements related to "Activity Based Costing".

## THE PATIENT PATHWAY

### Definition

In order to define a "patient pathway", various operative models can be used.

One of the most valid method is the model proposed by Massimiliano Panella according to the Tri-Health organization *Cincinnati* approach which can be synthesized in the following steps:

1. Identifying diseases
2. Building the work team
3. Selecting population
4. Representing the "patient pathway"
5. Pretesting of the represented pathway
6. Implementing pathway
7. Checking pathway
8. Improving pathway

All the previous experiences have arised the necessity to develop furtherly two issues [5]:

1. Representation techniques and methodologies.
2. Pretesting methodology.

In this article we focus our attention on the first issue; in particular we analyze an innovative use of traditional representation techniques in health domain.

### Representation Systems

In healthcare systems, traditional representation techniques have been used, but they have shown many weaknesses. We show here the most frequently used techniques:

- Flowchart: it is a tool allowing to have an immediate and schematic view of the process thanks to an easy readable notation, but this tool appears inefficacy in representing complex systems.
- IDEF0: it is a simple technique with a simple notation to represent the static elements of a system thanks to a schema characterized by input, output, constraints and resources. It is not so useful to represent process with many choicing steps.

As the complexity of a system increases, it is useful to have a representation technique which goes beyond the limits linked to the traditional tools [3].

We have choosen to adopt the UML language in order to reach this aim. UML, infact, includes a graphical notation which represents two views of the system:

- the static view shows information without time evolution providing a picture of the system in a certain instant;
- the dynamic view shows the time evolution of the system elements highlighting their interactions.

Nowadays UML is used mainly in the object oriented design. Nevertheless no one of its characteristic is referred only to software development, UML is a valid tool to represent complex realities and processes. Given the expressive efficacy of such language, it has been adopted as a base for the definition of a methodology for the representation of the health processes. UML has already been proposed in healthcare domain in previous important project such as HL7 international project which aims to provide a methodology to standardize messages exchange within heterogeneous IT systems supporting health processes [1]. This methodology provides also UML based models (UCM, RIM, IM, HMD) to support the requirements analysis and the solution design of health systems.

In our study, UML extension mechanisms have been analyzed to express better the elements of health domain using features which allow to add new semantic and syntax elements to the language. Such extensions consist in the introduction within the UML of some typical elements captured from health domain and other elements captured by the management field (as Activity Based Costing). This approach allows to take into account the concepts related to the costs too, granting an exhaustive representation of the entire health process.

## METHODOLOGY

### Steps in the Health Process Representation

As we have just explained it is important to define a conceptual model for process analysis: the concepts, the attributes and the associations have to be considered. following these steps [6]:

a. *general patient path*: general representation of the health path, which is based on the use of the use case UML diagram. This diagram provides a static view of the system showing its components (resource, input, output) and the elementary activities in which process can be decomposed.
b. *detailed patient path*: moving from general patient path, using a gerarchic approach, we arrive to a detailed representation of each elementary activity and interactions involved in health path. In this phase the static aspects of path are expressed through UML use case, while for the dynamic aspects we use UML sequence diagrams. A sequence diagram shows the interactions between objects in a time sequence.
c. *Costs analysis*: in this phase, using the modelling of the entire process obtained with the previous phases, it is possible to characterize clearly the essentials activities of the health process and associate them the direct costs, in order to give an economic evaluation of the process, according to the Activity Based Costing (ABC) concepts. This association is simplified with the sequence diagrams, in which we can define time and the other costs determining related to the activity[4].

## UML EXTENSION FOR THE HEALTH DOMAIN

UML is not a simple standard notation to describe domain models, but it is a well defined metamodel. A metamodel is a description of a set of constructs defined by a language used to model a system structure. In our case, we have added to the constructions provided by UML itself, other constructions to represent all the entities involved in health processes.

An health process is characterized by the delivering of a service which represents the offering for a request made by citizens. A set of resources involved in the execution of a set of activities are related to the delivering of such service. The aim of this set of activities is to reach both clinical and efficacy/efficiency purposes [4].

So, with a sufficient level of abstraction, we can represent an health process referring to the following characteristics:

1. Resource: this element is used for the delivering of a service (e.g.: medicals, nurses,…)
2. *Activity: a set of operations (e.g. checkup, drawing, …) which satisfies the following qualifications:*
   1. use of a set of critical resources;
   2. generation of a visible and measurable output;
   3. having one or more well defined internal or external "clients"
   4. auditing with one or more performance indicator.
3. *Input*: an element generating a service (e.g. patient, …)
4. *Output*: an element resulting from an activity (e.g. patient, medical report, …)
5. *Outcome*: a result of an action or process compared to a realistic and expected objectives.

We want to highlight that, while in manufacturer sector the outcome coincides with the expected result, in healthcare sector it could not coincide with the expected result. For example, within an health process, the obtained result could be a slower progressing of disease and not the complete recovery.

So, in order to support this schema, we have added some elements to the use case diagrams to make them more readable using the extension mechanisms provided by UML itself:

- *stereotypes*: they allow to extend the UML dictionary through the introduction of new elements related to the peculiarity of the analyzed domain;
- *constraints*: semantic restrictions introduced in order to explain constraints within domain problem.

We have added to the actor and use case UML stereotypes three other stereotypes which are typical of the health domain as shown below:

1. *Resource* which could belong to one of the following types:
   a. *human* (healthcare operator, nurses, medicals,…)
   b. *structural* (room, laboratory,…)
   c. *technical* (echograph,…)
2. *Input/output* which could belong to one of the following types:
   a. *human* (patient, familiar, medical)
   b. *informative* (laws, documents, ministry guide lines,…)
   c. *physical* (pattern, syringe,..)
3. *Activity* which, referred to the generated output, could belong to the following types:
   a. *auxiliary*: an activity which does not produce technical services (e.g. management activities, administrative activities,…);

b. *treatment*: an activity which produces a sanitary output (e.g. medical examination) or a not sanitary output (e.g. providing meals to patients) as long as it is related to the typical productive processes and it could belongs to one of the following types:
   i. *primary*: an activity which produces a complete output enjoyable from a subject external to the system that generated it. For example, a medical examination or a Laboratory test
   ii. *secondary:* an activity which produces a partial output that cannot be enjoyable directly, but it need to be composed with other secondary activities to generate a complete output. For example, a blood washing is a secondary activity within the Laboratory test primary activity.

In particular, *resource and input/output elements are actor stereotypes, while auxiliary activity, primary treatment and secondary treatment are use case stereotypes.*

## CONCEPTUAL MODEL DESCRIPTION

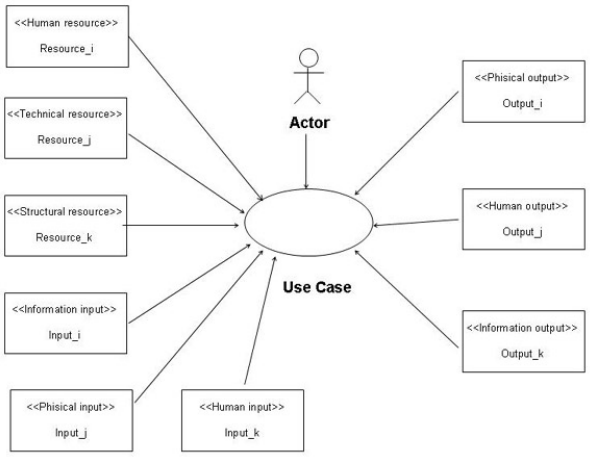
As just said, conceptual model allows to describe domain elements underlying the activities involved in realizing an health process. It is necessary to proceed with a first general description of the path in order to have an idea about how patient moves in the system. So we use the general path use case diagram to represent this path.

Each use case, in this context, will represent a macro-activity of the profile which can include, apart from the UML standard actor stereotype, the resource, input, output stereotypes.

To grant better readability, the diagram will assume the setting shown in figure 1 in which we see at the left side, input and resources and in the right side output and in the central side the use case. The actor is an external element to the system so it is in the upper side of the diagram.

Once we have described a "patient pathway", we can use a more detailed hierarchical approach. With this approach, each activity in the general path can be decomposed in sub activities to obtain the *detailed patient path*. In order to show this decomposition we present here a set of use case diagrams. Each of these elementary use cases is, in this context, assimilating to the activity concept of an health process according to the definition given above. As in the general patient path, in the detailed patient path, each activity can involve besides the actor stereotypes, the resource, input, output stereotypes. Moreover the use case stereotypes is substituted by the activity stereotype. We have to notice that, even if the graphical notation is unchanged, the new stereotype is identified by "<<…>>".

*Figure 1. Use Case Schema for the Description of a General "Patient Pathway"*




We show in Figure 2 the schema according to which diagrams have to be represented.

This diagram shows the existing of constraints in the auxiliary activity representation because the possible inputs and outputs are only informative.

Such activities, in fact, do not include the providing of a clinical or technical service, but involve only an information exchange (e.g. production of a report for a manager)

As described above, once we end the description of the path, which allow to understand the entities involved in the process, it is necessary to understand the way they interact. In order to model this dynamic aspect of the system we use the UML sequence diagrams. A sequence diagram shows, in fact, an interaction between objects projected in a time sequence. In particular it shows the objects participating to the interaction through the related «lifeline».

In this phase each activity presented in the detailed path is analytically examined in order to determine which are the exchanged messages between the different entities while they realize the activity.

In order to understand better this concept we show here a simple example: we suppose that the activity "take a sample" is one of the secondary activities of the detailed path, in which the involved entities are:

- nurse: an operator in charge of the execution of this activity can be modelled as a human resource;
- patient: person that take advantage from this treatment can be modelled as a human input for this activity;
- room (for taking samples): a room in which the treatment can be executed. It can be modelled as a structural resource;
- sample: the result of the treatment execution can be modelled as a physical output.

In Figure 3 we show the diagram describing the entire activity "Take a sample".

At this level of the analysis it is not so clear the way the entities contribute to realize the activity so we introduce the sequence diagram in which the messages exchanged between entities are highlighted.

The sequence diagram explains that patient occupies the room, nurse prepares the equipment and execute the blood exam. The exam execution generates a blood sample and some refuses (syringes, cotton wool,…), then patient vacates the room. Each activity requires a time interval which is expressed within parenthesis.

This level of detail can seem superfluous, but it has a double advantage:

- allowing to document precisely what happens in a sanitary structure, allowing decision maker to have a sort of behavioural protocol to which submitted persons have to adapt;
- providing many detailed information which can be useful during the costs analysis.

The efficacy of our approach can be appreciated by IT system analysts, but especially by health operators who need a way to describe complex sequences of actions related to an healthcare process. So we propose this study as a support for business modelling in healthcare system.

## AN EXAMPLE: THE PATH OF DEMENTED PATIENT

This example shows the phases of the demented patient pathway instituted in a centre for the Alzheimer treatment and care in Lecce (Italy).

*Figure 2. Schema of the Auxiliary Activity in the Description of the Detailed Patient Path*

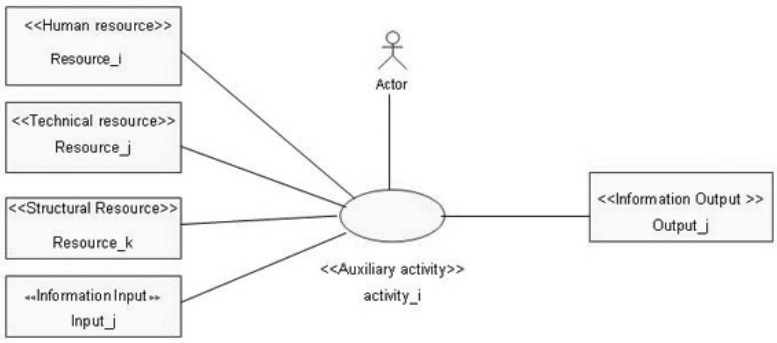
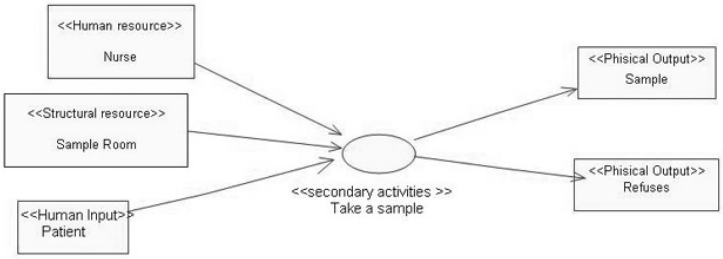



*Figure 3. A Secondary Treatment Example*




**Sending**

As shown in Figure 5, the diagram represents the patient sending moment to the Centre for care. The care giver (a person of the family responsible for patient) turns round the medical or the specialist for sending patient to the centre for suspicious dementia.

According to UML notation, family doctor and the specialist are represented as external actors given the fact that they are not directly involved in the realization of patient path.

**Path Start**

Patient path begins with reservation of visit. The diagram in Figure 6 shows the involved resources (nurse who register reservation and caregiver who does the request) and the output which in this case are only informative, that is appointment allocation and some information on how patient have to present for visit (on an empty stomach, etc.).

The sequence diagram in Figure 7 represents the sequence of the elementary operations which contribute to the activity execution (reservation, taking a blood sample,…).

**Reservation**

See Figure 7.

## CONCLUSIONS AND FUTURE WORK

The design and representation of a "patient pathway" is a complex process involving different actors so it needs a systematic work with periodical reviews to take into account the obtained results or the influences deriving from the external environment. In this paper we presented a model for the definition of such "patient pathway". We have introduced in UML some typical elements of health domain and other elements deriving from management, such as the elements related to "Activity based costing". This approach allows to represent exhaustively the entire health process, gathering the health costs related concepts and providing, thanks to UML, a support for developing applications related to these health processes.

Our research is continuing with the construction of a suite of tools to support the entire design process.

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*Figure 4. Description of the Secondary Treatment "Take a Sample" in a Sequence Diagram*

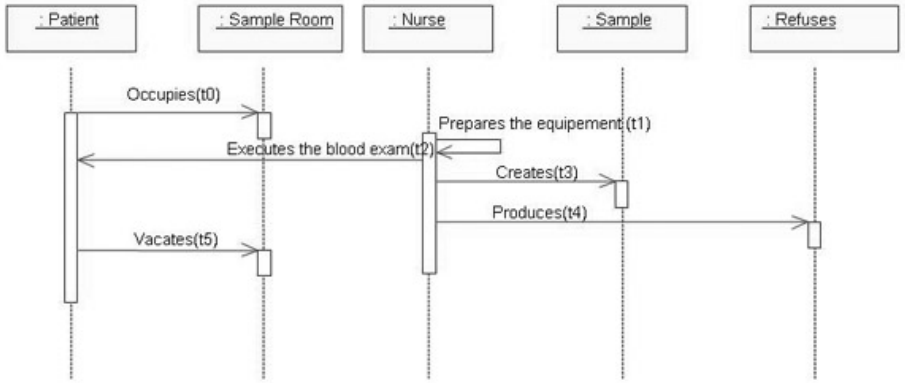


*Figure 5. The Patient Sending Moment to the Centre for Care*

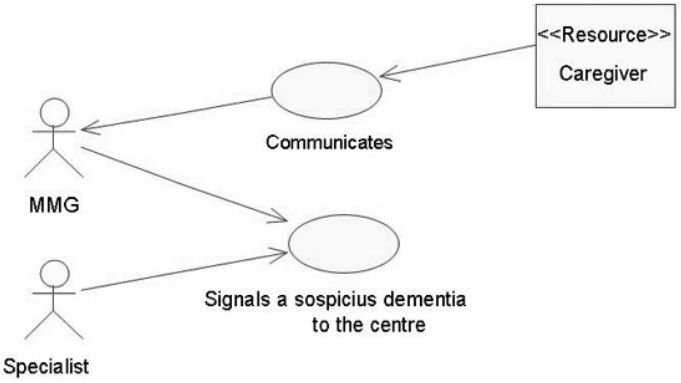


*Figure 6. The Patient Path Start*

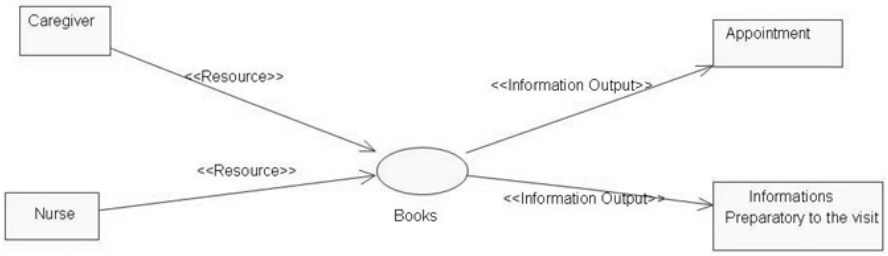


*Figure 7. The Reservation Path*