A multi-expert decision support system in medical ethics

Joël Colloc, N Léry

A multi-expert decision support system in medical ethics.

Joël Colloc
IAE, Université Lyon 3, 15, Quai Claude Bernard, 69007 Lyon France.
ESA CNRS 5047, MASS Université Claude Bernard Lyon 1, Bat 101,
43 Bd du 11 Novembre 1918, 69100 Villeurbanne France.
Adresse électronique : colloc@univ-lyon3.fr

Nicole Léry
Centre de Droit et Ethique de la Santé SEL - C.H.S. Le Vinatier
95, Boulevard Pinel 69677 Bron Cedex France.

`

ABSTRACT. In this article we present an oriented object approach to design the knowledge and reasoning modes involved in the medical ethical decision process. The S.E.L proposes guidelines, elaborated from ethical consultation experiences, to undertake appropriate decisions and actions. A great variety of knowledge is used during the decision process and, thus, require the design of a multi-expert decision support system. We illustrate our model in the domain of the vaccination. At last, we propose a case-based reasoning approach to benefit from the experience in solving previous cases.

RESUME. Dans cet article, nous présentons une approche orientée objet pour exprimer la connaissance et les modes de raisonnement intervenant dans le processus de décision en éthique médicale. Le SEL propose des repères, issus des expériences de consultations d'éthique, pour prendre des décisions appropriées et agir. Une grande variété de connaissances sont impliquées dans le processus de décision et ainsi nécessite la conception d'un système d'aide à la décision multi-expert. Nous illustrons notre modèle dans le domaine de la vaccination. Enfin, nous proposons une approche de raisonnement par cas pour bénéficier de l'expérience acquise de la résolution de cas précédents.

KEY WORDS : Object Oriented Model, legal knowledge, medical knowledge, reasoning modes, Case based reasoning, object similarity, cognitive schemas.

MOTS-CLES. Modèle orienté objet, connaissance juridique, connaissance médicale, modes de raisonnement, raisonnement par cas, similarité d'objets, schémas cognitifs.

1. Introduction

This work proposes an approach of a support decision system in medical ethics. The scope of medical ethics is to take appropriate decisions in actual situations, according to several knowledge domains.

The decision support system project, defined in [COLL 94], needs the cooperation of different kinds of expertise and abilities :

- the S.E.L. (Santé, Ethique et Liberté) is a medical team who owns a know-how in medical ethic decision,
- Object oriented models and methods suitable to analyse and to design medical information systems are proposed in [COLL89][COLL90][COLL92].

The SEL's consultations and advices are intended for all the people who were damaged by medical practises. The complaint is diversified. So, the S.E.L. proposes guidelines to take appropriate decisions. The decision criteria are included in a spiral decision process.

In this context, our scope is to automate the SEL's decision process in order to create a decision support system as defined in [COLL 94]. The medical ethics domain is very large. We reduced our study to the vaccination. First, only medical and legal aspects are considered because they are the main levels of the area and at these levels, there are serious arguments for 30% of the cases.

The wide range of problems needs the design of a multiexpert decision support system. An Object Oriented (O.O.) approach aims at designing the system.

The section 2 explains the context of the medical ethics decision. We highlight the variety and the intricacy of the knowledge involved in the decision process.

The section 3 presents the concepts of the O.O. model and the steps of the method used to design the knowledge domains and to model the interactions between them.

In the section 4, the model and the method are used to describe vaccinations, the legal fields and, to design a global cognitive schema which represents their interactions during the decision process.

At last, the section 5 proposes a case based reasoning approach to deal with ethic decisions.

2. The context of decisions in medical ethics

2.1 The required knowlege domains to take an ethic decision

Different knowledge domains are involved in elaborating the decision :

- Some of them concern the norms, the procedures, the references elaborated inside or outside but always near the human being and with the goal to propose an action.
- There is no appropriate answer to an ethic problem without technical ability. So, we need reliable and updated medical knowledge in order to determine what is the correct behaviour in a situation.
- The legal references are established social standards. The ethics is not the law but it is always necessary to consider available legal knowledge before taking difficult decisions, because the social aspect has already been debated.
- The medical ethics code and appropriate behaviour standards have been elaborated by physicians and summarized in a professional code. These guidelines should be respected by all the members of the profession.
- The recommendations and internal codes of specific organizations. Some organizations have defined internal rules in some specific fields. These rules, defined by the specialists of a medical domain, express a local consensus which is valuable when practical decisions have to be taken in this scope and when the law references are too fuzzy.
- The cultural and moral guidelines involve principles : philosophical, psychological concepts and convictions. We have to emphasize the distinction between moral and ethics. The closer to the practical decision you are, the more important the distance between moral and ethics is.

Some criteria are minor (less than 5% of cases), but they define the needy ethics which take into account the inductive aspect.

- The ethics decisions elaborate a compromise. The ethical act is beyond all the needed data and documentation, even if, in a given situation, getting information is always necessary to take a decision in a rational way. The decision is not arising from

scratch or from already elaborated ideas, but by a metabolism which is testing it against the constraints of the present situation, in order to make the least bad compromise. The more responsible one is, the more one knows how difficult, questionable, discomfortable the decisions are.

Thus, the final action is undertaken by someone alone; however, it has been elaborated with the help of other people and advice and consequently, the action is becoming a collective act.

- The choice criteria hierarchy. The scope of the ethical act is both to legitimate and to regulate, that is to provide a compromise between the arguments provided by the concerned actors. The knowledge domain spiral represents a hierarchy of criteria, which are, in turn, involved in elaborating the decision (figure 1).

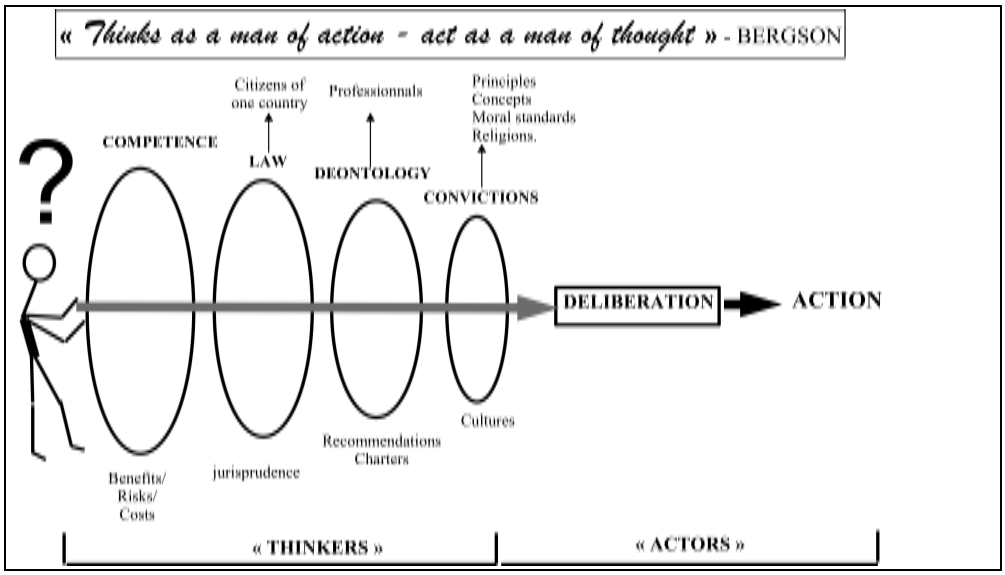

figure.1 : *The S.E.L's Spiral of ethical decision process*

2.2. The heterogeneous and the experimental nature of medical knowledge.

Medecine is a science based on the human organism observation.

The human being complexity forbids the exhaustive representation of organism mechanisms and moreover of disease appearance.

In spite of the science progress, the physician must reason within an uncertain universe. Different uncertainty reasons were stated in [COLL 92] :

- **Medical theories**, based on the studies of clinical signs and on experiments, can vary with medical schools.
- **Individuals**, the same disease can express itself in different manners for each patient.
- **Topography**, some diseases are multifocal, they show various clinical pictures according to the damaged organ or apparatus. For example : bones tuberculosis and pulmonary phthisis are the two forms of the same disease, (sharing the same etiology).
- **Periodicity**, diseases are dynamic processes, clinical syndromes are only pathology snapshots, corresponding to evolution steps. Some diseases progress in a linear way (step by step). For example - syphilis displays three successive stages. Others progress in a cyclic manner such as the duodenal ulcer or the herpes infection. Therefore, time is a major factor when describing pathologies.
- **Chosen therapy**, an inappropriate treatment or another underlying disease can interfere and give unusual clinical aspects. Futhermore, they can produce iatrogenic diseases, expression of toxic mechanisms which need supplementary arguments to connect causes and effects together.
- **Science progress**, medical knowledge is continually changing according to the new discoveries of researchers.

In order to propose a decision support system in medical ethics, we at least have to model the most important knowledge domains represented in the spiral and their

interactions. We need to use an object oriented model able to deal with the semantic complexity of all the involved criteria.

3. A method to design medical and legal knowledge bases and their interactions.

3.1 The object oriented model concepts

In our model [COLL 89][COLL 90], the objects are nested in each other. According to the domain, a unit corresponding to a reference object type (or level 0) has to be defined : each instance of this type is a unique object.

This notion defines a boundary between the internal level and the external level : all the objects with a superior or equal size belong to the external environment while the smaller objects are in the internal environment, inside the "unique object". The latter objects that contribute to build the unique object, are called sub-objects.

The internal structure represents the content of the object and its composing sub-objects. The external environment expresses the relationship of an object with the others.

At any time, each sub-object can be seen, at the reference level by selecting the corresponding object type as the reference type. Its proper sub-objects build up its internal structure. We call zoom effect this adapted perception of objects.

The figure 2 presents the external and internal levels of the O.O. model.

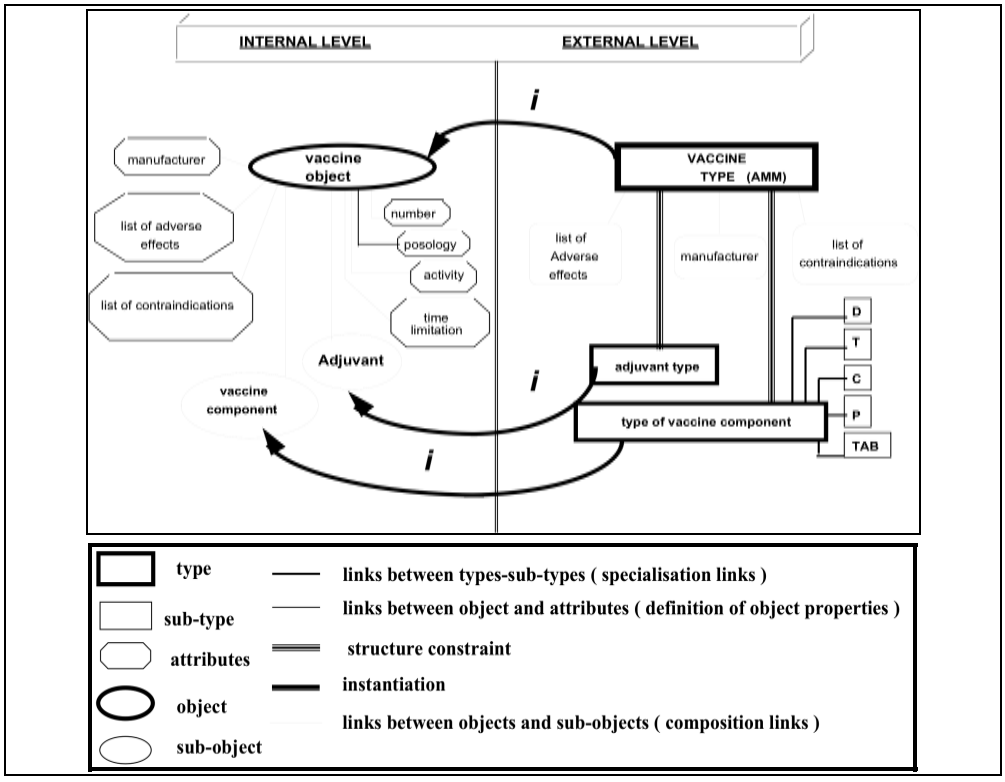

figure 2 : Vaccine object type

3.1.1. The internal level : the object composition level

It includes the (Is-part-of) aggregation relationship of sub-objects, the (Has-a) relationship which is grouping all the attributes of one object. The aggregation relationship establish a multiple upward inheritance which gives the composite object access to the composing sub-objects properties.

The internal level encapsulates attributes and functions which represent the static characteristics and the behaviour of the objects. The object constraints are either static : the structures, the attributes, the cardinalities constraints, or dynamic when they are functions of time.

The spontaneous evolution of the object state is translated by the object dynamical functions. At any time, these functions automatically modify the composition links and the attributes reference values,.

Object evaluation functions compare the object structure (its composing sub-objects) and the attribute values to other similar objects.

This feature is implemented by means of computed distances and will be used to provide the case-based reasoning approach presented in section 5.

3.1.2. The external level : the type level.

It includes the (Is-a) generalization / specialization relationships between object types and object sub-types. These relationships establish a type hierarchy and a simple descending inheritance which transfer object type properties to its sub-types.

The evaluation functions belonging to the instances of the application object type, assess all the object type instances in the knowledge base.

The model makes a distinction between type concept (object structure and properties) and class concept (a set of instances).

3.1.3. Links between external level and internal level

. Instantiation

This mechanism determines new objects in accordance with each type.

. Encapsulation and interface functions

The input (or affectation) functions verify the values to be given to the object attributes and then affect them. The output (or reading) functions give us the state of an object.

. Application object type

The application object type is a predefined system type, whose aim is to describe applications which suit several user needs. The objects of application type encapsulate :

- data metaattributes which are used to represent the intermediate states and the results of a treatment or a reasoning step,

- metafunctions which are designed to define existing relationships, else than the composition, that exists between different domain knowledge objects of some types, involved in a reasoning step.

3.2 The method to design the knowledge bases

3.2.1. Preliminary steps

An opportuneness study and a feasibility study [BONN 86] successively determine the project interest, the needed and available human and material resources for the project achievement.

3.2.2. The conceptual step

First, the experts, with the help of a knowledge engineer, have to define the knowledge domains concerned with the expert system project and their relationships [HARM 90].

Then, during a domain describing stage, the experts must define the characteristics, the structure, the behaviour of the instances belonging to the object types involved in each knowledge domain.

Two kinds of object types have to be distinguished :

- concrete object types which define real world objects (structure and behaviour) according to the perception provided by at least one of the five human sensory organs. A car is a concrete object.

- abstract object types are concepts generated by human cognitive activity. A disease is an abstract object defined through a conceptual framework.

So, knowledge object types should be divided up into one of the two categories - concrete object types and abstract object types. The description of object structures may take place in an ascending or descending manner.

. The top down design

For each complex object type of the domain, the experts must determine the number and the type of the sub-objects needed to build the inner composition of their instances. This choice allows to accomodate the expertise level.

In order to realize the task, it is helpful to select significant knowledge instances. For each knowledge object, experts have to list their sub-objects (and their respective types), to describe them in turn, and so on, till reaching the composition hierarchy leave level, where simple sub-objects, which only own attributes, are found.

At this stage, the type of a knowledge complex object is expressed by listing the types of sub-objects involved at each level of the hierarchy composition knowledge instances.

It is helpful to create several versions of object types, coexisting without conflict, to represent multiple expert advices.

At this point, the attribute constraints of each object type are defined. At last, the object type set of each knowledge domain is represented by a diagram and submitted to the experts approval and correction.

. The bottom up design

The experts build a library of simple object types coming with their qualifier attributes and respective constraints. Then, the experts use already defined simpler object types, whose instances are selected as sub-objects. This allows to build the composition hierarchy of more and more complex objects, in an incremental way.

The complex object type is expressed by listing all the types of the sub-objects involved in the composition hierarchy. The advantages of this approach are :

- the ability to add new sub-object types at any time of the design,
- the possibility to use preexisting object types whose quality can be tested, before their implication, in more complex object types.

Generally, ascendant and descendant method are combined. A reference dictionary gathers object-type identifiers.

The next stage is concerned with the definition of interface functions, evaluation functions, dynamic functions which allow to express object states, attribute values, at any time of the object existence. All these features are included in respective object type headers. Domain objects and types constitute the knowledge base.

3.2.3. The application description step

During this step, the experts express information needs for the different users, by defining application abstract object types [BART 90].

An application object interact with objects belonging to one or several knowledge domains of the base built at the previous step. Application objects express the different reasoning step (similarity, deduction...) performed on knowledge objects. Analogy is implemented through a case based reasoning approach presented in section 5.

3.2.4. Implementation step

Then, there are classical steps composing the life cycle of an information system : prototyping, control and validation of the knowledge base, real situation evaluation, maintenance [HARM 90].

4. Application to medical ethic decision

In the following section, we, in detail, apply two steps of the method : the description of the knowledge domains and the description of the applications.

The first step of the method allows to provide a knowledge representation of the antitetanus vaccination. The second step describes the reasoning modes used to take a decision in this domain.

4.1 Description of the knowledge domains

The knowledge domains related to the vaccination and ethical problems take into account criteria widespread on the SEL's spiral. But, in fact, a large part of cases are merely solved with the help of technical and legal knowledge. Technical criteria include the different medical practise modes according to the physician's specialities.

NB : In France some physicians practise in a private consultation office while others are working in a hospital or in public health services.

The legal domain defines the duties of the physicians and the right procedure of the vaccination described in the French legislation. The legal references are the civil law, the national health code, the deontological code, national and European charters or recommendations. However, the moral and cultural criteria are concerned with the vaccination.

Our application domains can be represented by some object types the instances of which are organized in composition hierarchies. The list of the recorded object types is as follows :

patient, physician, medical contract (between the patient and the physician), vaccine, vaccine component, undesirable effect, medical document, consultation, check-up, medical act, diagnosis, fault, procedure.

The description of the knowledge domains aims at representing the structure of object types through the O.O. model. The illustration of this conceptual step is presented through the vaccine object type (figure 2). We explain the design of the vaccine object as follows :

. The internal level

The diagram shows relations between a vaccine object, its components and its attributes. Composition relationships are set between the vaccine object and all its sub-objects because each vaccine must at least contain one adjuvant and one or several vaccine object components.

These sub-objects influence the nature of undesirable effects (for example : allergy caused by the adjuvant) and the list of the contraindications to vaccine dispensation.

. The external level :

The specialization/generalization relationships are defined between object types and their sub-types.

For example, the vaccine component type is specialized in several sub-types : tetanus, diphtheria, poliomyelitis, typhoid, whooping...

The vaccine type is a base type, it provides a framework for most available vaccines. Some sub-types are not represented on the schema to keep it readable.

4.2 Description of applications :

The next step of the method describes the necessary interactions between domain object types to design the application. The appropriate reasoning modes used by experts to solve a problem are expressed by actions executed by objects. The process assumes the conceptual definition of reasoning modes through a cognitive diagram.

Then, an application object type is defined in an interactive way to represent the succession of reasoning steps and the involved object types.

The information flows exchange between domain objects is defined by Experts Reasoning Models named cognitive schemes [COLL 92].

The representation of the reasoning modes involved in the ethical decision process in vaccination is illustrated by an actual case. This example shows that the problem has to be split in juridical and medical aspects. In order to model the decision process, the interactions between the medical and juridical fields must be represented as well.

4.2.1 The actual case presentation

The problem to solve is to determine if the physician's decision to abstain from administrating the antitetanus serum caused the patient's death.

We give one summary of the facts provided by the SEL :

Mister G, 52 years old, gardener, wounded his finger with a thorn. After a visit to a phamacist, he went to a doctor. The check-up disclosed a high albumine rate in his urine. The patient was not vaccinated. Therefore, the practitioner considered that the serum injection was too dangerous because the patient albumine rate was to high. So he prescribed bandages and one week later, the patient was hospitalized for a tetanus with

« trismus ». At the hospital an injection of 10000 serum unities induced an allergic reaction with an urticarian eruption and general troubles which caused the patient's death.

A procedure was engaged and the legal events were described in the following :

- One first expert's report concluded that the injection could not have changed the course of the disease.

- The dispute was brought before the Court of Summary Jurisdiction and the President found the physician not guilty, because it was not proved that the death was the direct consequence of the injection lack. Finally the doctor was acquited.

- The Court of Appeal (second level of juridiction) gave another decision : the presence of albumine was not an absolute contraindication; the troubles described at the hospital were consecutive to a lack of precautions. So, the patient's death is the direct result of the doctor's fault. He was declared guilty of manslaughter.

- The Supreme Court of Appeal rejected the petition as a function of 319, 320, of penal code; and, 1382, 1383 of civil law. In this case, the use of a Decision Support System (DSS) would have tried to answer these two questions :

- what are the proceedings that the victim's family could institute ?

- What are the medical answers for a physician in the same situation ?

These two kinds of questions match with the two fields : the technical field (conditions of vaccination) and the legal field (compulsory vaccination, and medical liability for the doctor). We propose to design these two fields and to show the reasoning modes used.

4.2.2 Design of the technical field

We modelize reasoning modes through a cognitive diagram which describes the reasoning steps of the case which concern the medical field. Each reasoning stage of the cognitive diagram will be detailed with an expert reasoning model. The cognitive diagram shows the object types and their attributes which give useful information to understand the decision process.

This cognitive diagram allows the modelisation of different cognitive schemes such as :

- the medical contract between the patient and the physician. The check-up allows to get the necessary information concerning the patient and the physician practise mode.

- The diagnosis is the result of the examination, informations coming from the patient case-history and the physician knowledge.

- The medical acts are based on the diagnosis and can be delegated to nurses.

- The prescriptions are elaborated according to the previous steps.

These diagrams will describe message exchanges between the system objects.

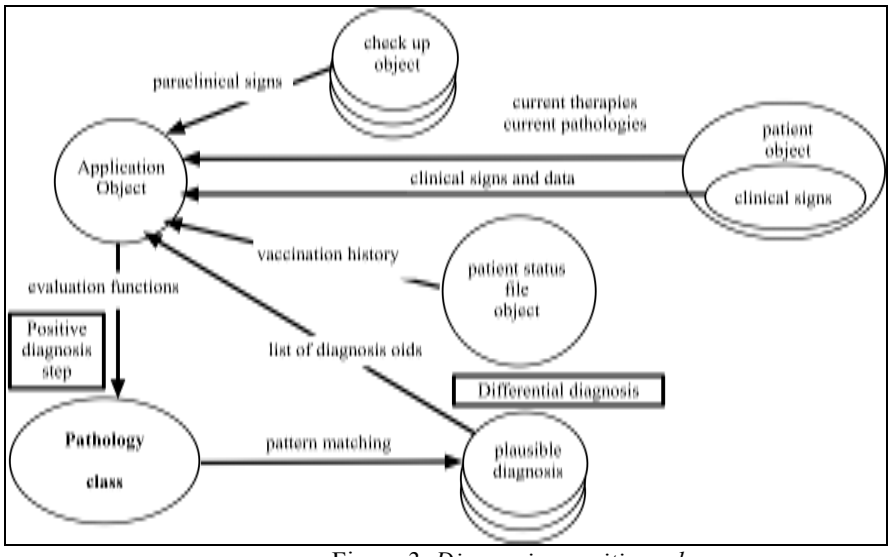

Figure 3. *Diagnosis cognitive schema*

For example, the previous figure 3 describes the diagnosis cognitive schema. The diagnosis is based on medical and surgical semiology, that is to say on the study of clinical signs and events which leads the physician to identify the disease.

During the **positive diagnosis step,** the physician considers current complaints, medical history, genetic and social background; moreover through the examination of the patient, he searches for clinical signs that we classify in three different types : pathognomonic signs (characterizing a disease), evocative sign (inducing to investigate some disease hypotheses), accessory signs (completing the clinical picture). During the positive diagnosis, the physician is making hypotheses relevant to the patient clinical state.

During the **differential diagnosis step,** the physician is searching for the existence or the lack of specific signs in order to eliminate elaborated hypotheses, those which are not relevant, from the previous ones.

In the figure 3, the evaluation functions choose several diagnosis objects matching with the patient's pathologies and characteristics. The list of the selected objects will be recorded in the application object. We develop similarity algorithms to implement the structural pattern matching of object [COLL 93].

4.2.3. The design of legal field :

In this case we will pay a particular attention to the appeal decision.

The reasoning modes involved in the case define the cognitive diagram of this field.

Four reasoning steps are defined :

- **The legal request definition** : a fault is defined by comparing the physician's acts with the appropriate behaviour defined by the state of the art in medical practise. If there is a fault, it is compared to the relevant instances of classes of legislative texts which implement a taxonomy and describe some categories of mistakes and misbehaviours.

- **The legal fault definition** : the system has to check if the anomaly matches with the transgression of one of the relevant texts selected in statute-books.

- **The jurisdiction choice** : the chosen text objects will allow the appreciation of the fault as an offense, crime, contravention defined in the penal and/or civil or administrative law. The appreciation of the fault and the delay of action help to choose the best legal procedure.

- The judgement stage : it represents the result of the juridical procedure.

The next figure shows the cognitive diagram of the juridical field.

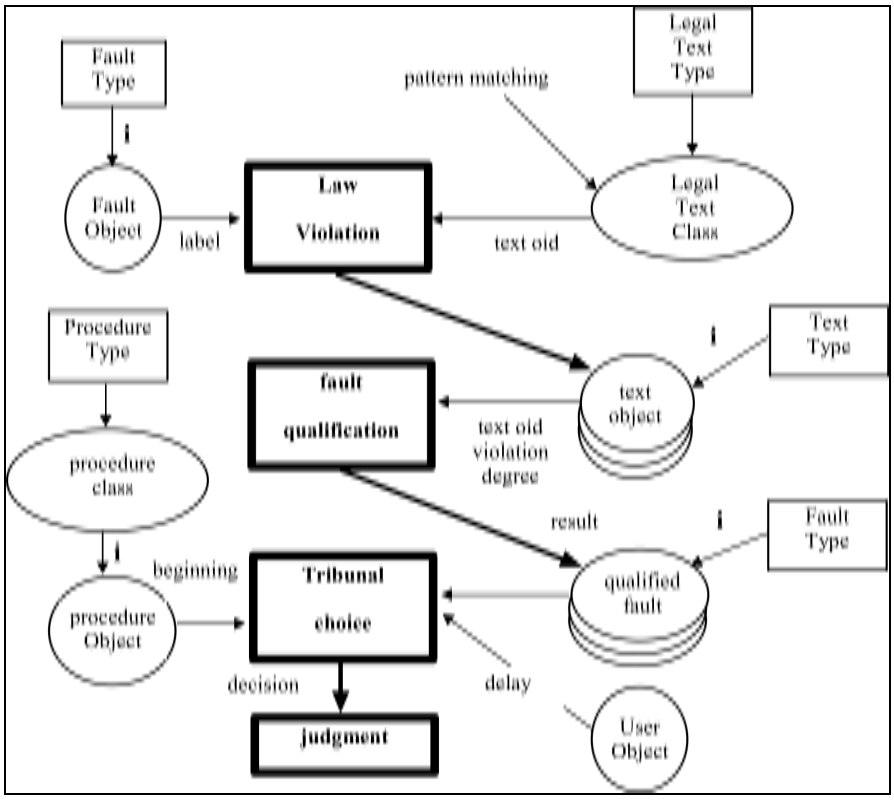

Figure 4. *Juridical cognitive schema*

4.3. Cooperation between knowledge domains

The links between the medical and the legal domains must be achieved through the model.

The general cognitive diagram shows that the system must be able to determine, according to the legislation, if the physician did a mistake or not. The figure 5. provides the general cognitive schema which establish the link between the medical domain and the juridical domain.

The schema shows the different object types involved in the decision process.

The legislation defines three types of fault corresponding to the physician's acts :

- cases where the physician do not interfere when he should do,
- cases where the physician interferes when he should not do.
- cases where the physician acts are not appropriate, according to the current medical art criteria.

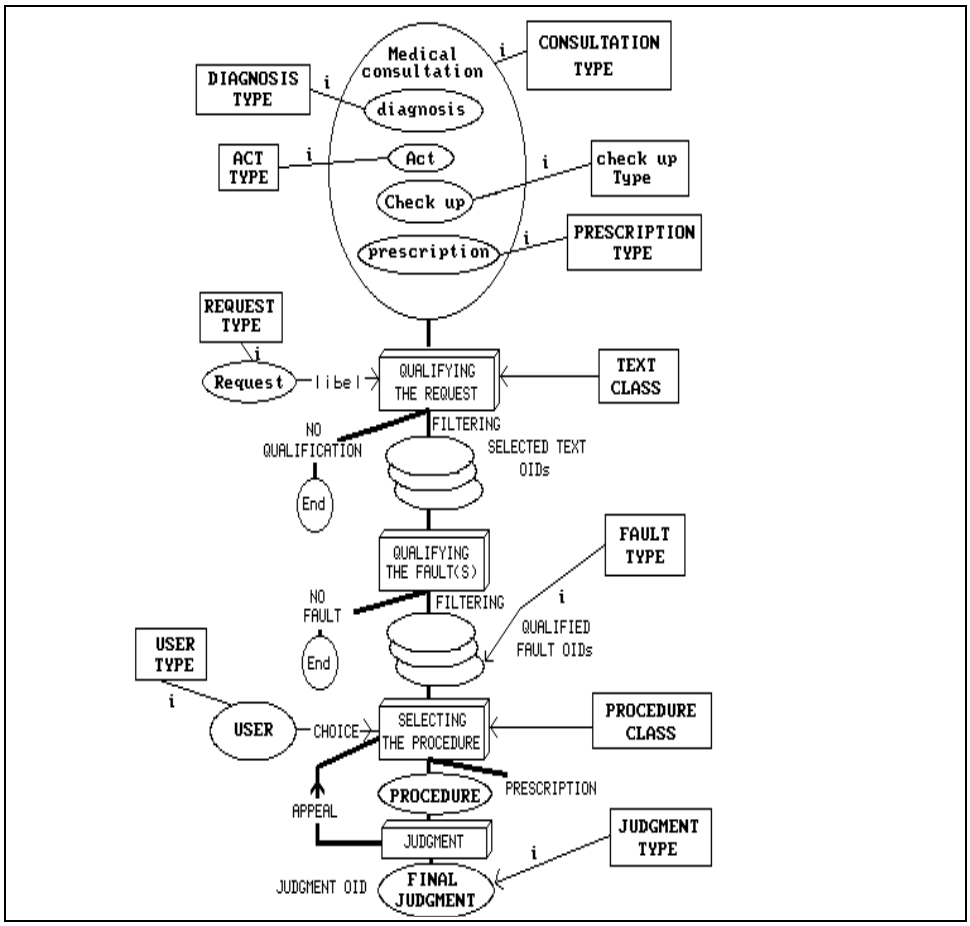

Figure 5. *General cognitive schema*

Different kinds of faults can occur at any consultation step : diagnosis, therapy...

The links between the fields express the physician responsability which is defined by a damage, the fault and the causal relationship between the fault and the damage, thus, the involving values provided by medical and legal objects. The judge examines the physician's responsability to take his decision.

However, each medical ethic problem is unique and the need of technical references make the Case-Based Reasoning (CBR) approach, presented in the next section, suitable to model the decision process.

5. A case based reasoning approach of the ethic decision

The Case Base CBR reasoning is a powerful concept which provides an analogic reasoning mode in problem solving [Keane, 1993]. This capability allows to enhance medical ethic knowledge by comparing new cases with stored indexed previous cases, to retrieve those similar and to apply the corresponding decision process to the new problem, expecting that what was good one time, will be good several times [Gupta, 1994].

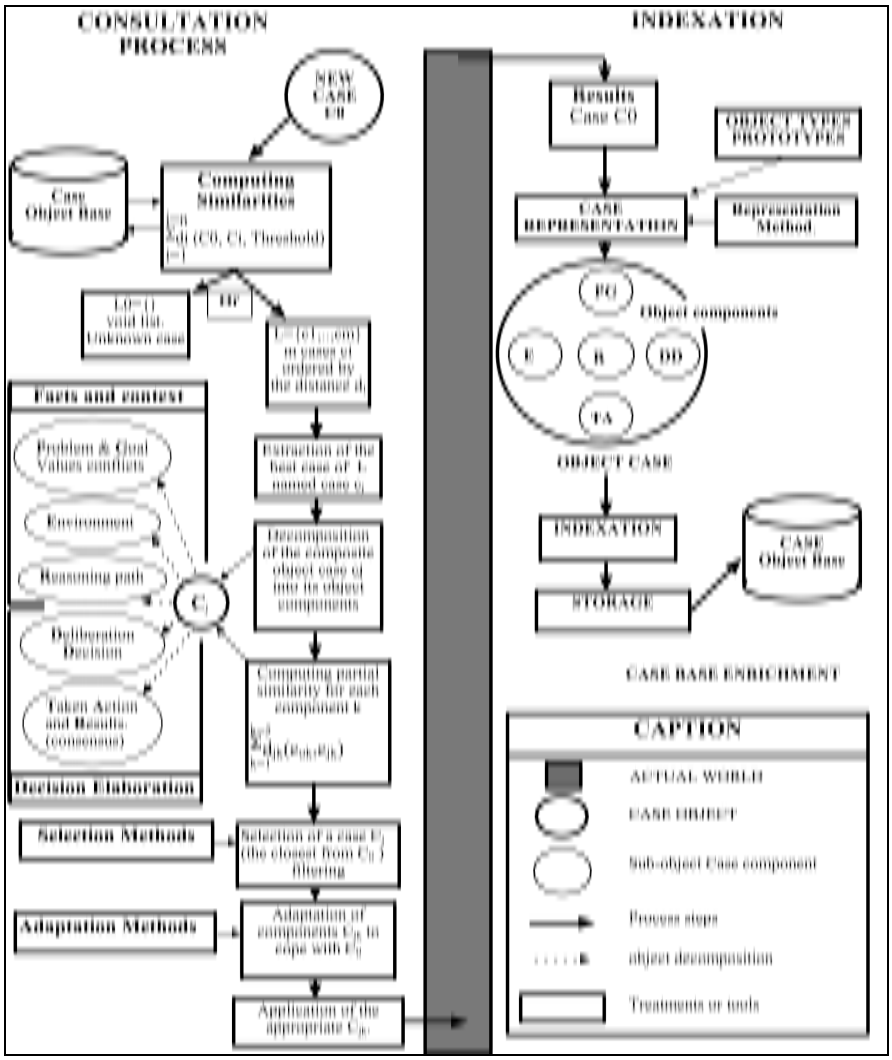

Figure 6. *The Case Based Reasoning process.*

The figure 6 shows a CBR architecture which includes the appropriate steps to deal with analogic reasoning. It comes with an indexed case object base and a distance to compute object partial similarity [Coll 93] between the object different components defining the stored cases and the new case under consideration [Wang 90].

Two main features are provided : case storing through the « indexation module » (right part of the figure 6) and case retrieval handled by the « consultation process » (left part of the figure 6).

These two complementary features implement the CBR cycle through the case object base which defines the memory of the system.

The case object base contains patient cases composed of the problem and goal definitions, the environment facts, the reasoning path, the decision, the action and the result of the taken actions.

6. Conclusion

This article describes the context of medical ethical decision through the experience of SEL's medical consultation. We focus on the vaccination problems and propose to automate the corresponding decision process.

The article shows that the object oriented model and its method are appropriate to express the semantic complexity of the knowledge domains involved in the decision.

The reasoning steps are represented with the help of cognitive schemes which are useful to describe the interactions between knowledge objects and classes.

The sequence of the reasoning steps of the decision process is well represented but we have not yet an appropriate formalism to model causal links between legal and medical information.

The Case Based Reasoning (CBR) approach consists of solving new problems with the help of previously stored indexed similar experiences. We presented a CBR process which is suitable to represent medical ethic cases, to retrieve them and thus, to allow to solve new ethics problems using analogical reasoning capabilities.

The main problem in Case Based Reasoning is to match similar cases, to classify and index them in order to store them in a clever manner. In a CBR object oriented approach one must represent and record the knowledge involved in decision and the decision process itself.

7. References

[BART 80] BARTHES J.P and al. « Objects and artificial intelligence », *Proceedings of the third national days PRC-GDR Artificial Intelligence*, Paris, 1980.

[BEAU 93] BEAUBOUCHER N., « ANAIS : Case-Based Reasoning system in an environment of problems solving », *Proceedings of VOLCAN IA'93*, Clermont-Ferrand, 1993.

[BONN 86] BONNET A., HATON J.P., « Systèmes Experts, vers la maîtrise industrielle », Edition Masson 1988.

[COLL 89] COLLOC J., BOULANGER D., « Un modèle objet pour la représentation de connaissances empiriques » *In proceedings Colloque ICO'89 Informatique Cognitive des Organisations*, Quebec, Juin , 1989 EdMoulin B. et Simian G.Limonest, 1989, pp 119-140.

[COLL 92] COLLOC J., BOULANGER D., « Object Oriented Model and Method Applied to Build an Expert System for intoxication Diagnoses *»., In actes du Congrès SEIGE'92 NICE France*, Ed. SEIGE, 1992 - Tome 2 : Journée du 18/09/1992.

[COLL 93] COLLOC J., BOULANGER D., « Automatic Knowledge Acquisition for Object Oriented Expert Systems », *proceedings of the 13th International Conference : Artificial Intelligence, Expert Systems, Natural Language,* Avignon, France, May 1993, pp. 99-108.

[COLL 94] COLLOC J., BOULANGER D., LERY N., « Pour un système interactif d'aide à la décision en éthique médicale. » *in proceedings, SYSTED'94, 5th Int. Conference on Systems Sciences in Health-social Services for the Elderly and the Disabled*., ed. by J.C. Rey, C. Tilquin, Genève CICG, 1994, pp. 711-717.

[COUL 90] COULON D., BOISVIEUX J.F., BOURELLY L. et al., « Analogy reasoning in artificial intelligence »*, proceedings of the third national days PRC-GDR Artificial Intelligence*, Paris.

[GABR 82] GABRIELLI E.R., BUFFALO M.D., « PRAKTICE - an advanced clinical information system, in Computers for medical office and patient management », ed. Van Nostrand Reinhold cie, ed by Day S.B. and Brandejs J.F., 1982.

[GUPT 94] GUPTA U.G., « How cas-based reasoning solves new problems », Interfaces, Vol 24, n. 6, 1994.

[HARM 90] HARMON P., SAWYER B.,« Creating Expert Systems for Business Industry », New york, Ed John Wiley & Sons Inc 1990.

[KAIN 94] KAINDL H., Object-oriented approaches in software engineering and artificial intelligence, JOOP, Vol 6, N°8, SIGS Publication, January 1994.

[KEAN 93] KEANE M. T., « Analogical Asides on Case-Based Reasoning. », *proceedings of 1st European Workshop WCBR-93, Lecture Notes in Artificial Intelligence*, N°837, Topics in Case-Based-Reasoning, Spriner-Verlag, November 1993.

[LERY 89] LERY L., LERY N. , « Approche méthodologique d'évaluation éthique des pratiques en vaccinologie, application aux essais cliniques des vaccins », Réunion technique sur la production industrielle et la distribution des produits biologiques en Asie, Ministère des Affaires Etrangères, Paris, dec 1989.

[LERY 90] LERY N., « Droit et éthique de la santé : l'expérience d'une consultation », Médecine et hygiène, 48, pp 2161-2166, 1990.

[WANG 90] WANG T.L., SHASHA D., « Query Processing for Distance Metrics », *Proceedings of 16th VLDB Conference*, Brisbane, Australia, 1990.