Cooperative Work in a Health Care Network Through a Virtual Staff

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Abstract. The paper presents a software tool called Virtual Staff which enables members of a healthcare network to visualize their collective reasoning: in order to diagnose the pathology of the patient (according to the symptoms expressed by the patient, the observations or analyses of the doctor and the already known health problems of this patient), or in order to determine the best possible therapeutic procedures. This Virtual Staff aims at offering to the users a service of support to cooperative reasoning, during the phases of elaboration of diagnosis or therapeutic decision and a service of constitution of a memory of decisions of the community constituted by the members of the care network. Another goal of Virtual Staff is to prepare repository of patient cases which will be reused for decision support in new cases.

Keywords: ontologies, knowledge management, cooperative work, decision-making support, QOC, SOAP, health network.

1. Context : Needs in a Care Network

The collaborative project *"Ligne de Vie"* (*Life Line*), aims at developing a knowledge management (KM) tool for a care network. Specialised in a particular domain or in a specific pathology, a care network is a health network gathering all the actors intervening in the care or follow-up processes. The objective of the network is to ease (a) communication and collaboration among these actors in spite of their physical distance, (b) the regular follow-up of the patient et (c) the respect of best practices inside the network.

The ideas proposed by the industrial partner for launching the project Ligne de Vie stem from fifteen years of experiences in health domain and from contacts with a network dedicated to diabetes: Nautilus offers a software for management of electronic medical record, Episodus, relying on a problem-oriented vision of the patient records and articulated around the notion of « Life Line » enabling to represent the life of the patient from his/her birth till his/her death with all the health problems encountered by this patient. As long as the patient still suffers from a problem, this problem remains open. When the patient gets completely cured from it, the problem is closed. Figure 1 shows an example of such life line of a patient.

This article focuses on a software tool called *Virtual Staff* which enables network members to *visualize their collective reasoning*: in order to diagnose the pathology of the patient (according to the symptoms expressed by the patient, the observations or analyses of the doctor and the already known health problems of this patient), or in order to determine the best possible therapeutic procedures. This Virtual Staff should offer to the users *a service of support to cooperative reasoning*, during the phases of elaboration of diagnosis or therapeutic decision and *a service of constitution of an organisational memory* – the memory of decisions of the community constituted by the members of the care network.

In the next session, we will explain the objectives of the Virtual Staff (VS). Then, we will describe the models of SOAP and QOC graphs on which the VS relies and we will present the architecture and functions of the VS, before illustrating cooperation the VS enables for the members of the care network. Finally we will discuss the interest of the software for KM in a health-centred community and then conclude.

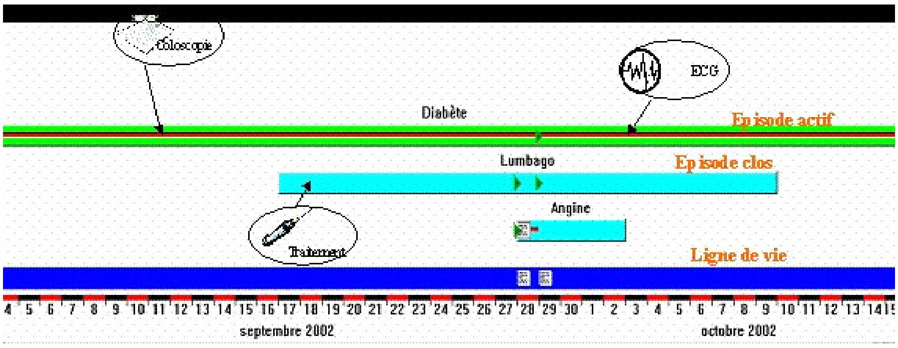

Fig. 1. Episodus representation of life-line

2. Objectives of the Virtual Staff

In the hospital, the unity of location and of time allows the doctors to meet as a staff in order to discuss about the decisions to take. In a care network, the Virtual Staff aims to be a collaborative work supporting tool, allowing the real time update and history of therapeutic decisions. As an *electronic board* where each one can note information readable by the other members of the team, it constitutes a discussion support that may be synchronous (if the participants take part to the discussion at the same time or in the same place) or asynchronous (if each one accesses it at the moment appropriate to him/her). Starting from the patient's health problems, the members of the team will formulate diagnostic hypotheses and proposals for a treatment. Via this Virtual Staff, the care team will connect the various elements of the patient record useful for the discussion, and thus will converge in an asynchronous way towards the definition of new health problems and of new therapeutic actions. The formulation of diagnostic hypotheses is a priori reserved to the medical actors, whereas the discussion on the treatment could sometimes imply non medical professionals (for example, a welfare officer could emit arguments against the choice of a heavy treatment incompatible with housing conditions of the patient).

We suppose that many cases will be created *asynchronously* by *multiple users*. This requires to visualize and store all information on the patient case, including multi-user and temporal aspects. Another objective of Virtual Staff is to collect solved cases in a special *repository* and to reuse them for retrieving past patient cases similar to a new patient case to solve. This kind of reasoning is similar to case-based reasoning [11].

3. Models of SOAP and QOC graphs

3.1. Weed's SOAP Model

In Virtual Staff, the dependencies between the various diagnostic and therapeutic hypotheses can be represented through a graph using the concepts defined in the Nautilus ontology. The doctor will reason by linking the health problems to the symptoms, the clinical signs and the observations in order to propose health care procedures.

The Virtual Staff can thus rest on the SOAP model (Subjective, Objective, Assessment, Plan) used by the medical community [15]. In this model:

- the S nodes describe current symptoms and clinical signs of the patient,
- the O nodes describe analyses or observations of the physician,
- the A nodes correspond to the diseases or health problems of the patient,
- and the P nodes correspond to the procedures or action plans set up in order to solve the health problems.

This SOAP model is used in the medical community to structure a patient record. Therefore, its use to structure the doctor's reasoning - that relies on the same concepts - seems natural.

3.2. QOC Model (Question-Options-Criteria)

Sometimes, the doctor may need to visualize all the possible solutions and the arguments in their favour or against them. The QOC model (Question Options Criteria) [10], used by CSCW community for support to decision-making or for design rationale in a project, can then be useful. In this model, a question Q corresponds to a problem to solve. To solve the question Q, several Options are thought out, with, for each option, the criteria in its favour and the criteria against it: each option is thus connected positively or negatively to criteria. The QOC graph is reduced to a tree if no criterion is linked to several options.

Two types of questions are possible for the Virtual Staff:

- *Diagnosis of a pathology* (i.e. find the right A in the SOAP model): Which pathology explains the clinical signs of the patient?
- *Search of a prescription* (i.e. find the right P in the SOAP model): Which action plan will enable to treat the diagnosed pathology?

In the Virtual Staff, among the criteria to be satisfied, there are the patient's symptoms and the doctor's observations: for a question about the patient's pathology, each possible option will be linked by a positive influence link to the symptoms and observations compatible with this option, and by a negative link to the symptoms or observations rather incompatible with this pathology. The criteria will thus consist of S or O nodes of the SOAP model but they may also sometimes correspond to A or P nodes, if some diseases are incompatible or if some health care procedures are exclusive.

For support to decision on a treatment to cure the diagnosed pathology, the options will be the possible treatments, each one connected by a positive link to the criteria encouraging to choose it and by a negative link to the criteria inciting to reject it.

3.3. Combination of graphs in Virtual Staff

In the Virtual Staff, we combine both models: SOAP to visualize the medical record and QOC in phase of decision to choose between pathologies or between action plans. Each patient case consists of exactly one SOAP graph and any number of QOC graphs. SOAP graph is divided into four zones according to the four SOAP types of nodes (Assessment, Objective, Subjective and Plan) and for better clarity, nodes of same type are clustered in the corresponding zone.

Any *A* or *P* node could have an associated QOC graph. In Virtual Staff we distinguish between open and closed QOC graphs. An open QOC graph corresponds to a support for choosing a decision not yet taken, while a closed QOC graph corresponds to a decision already taken. Figure 2. shows basic user interface of both graph types.

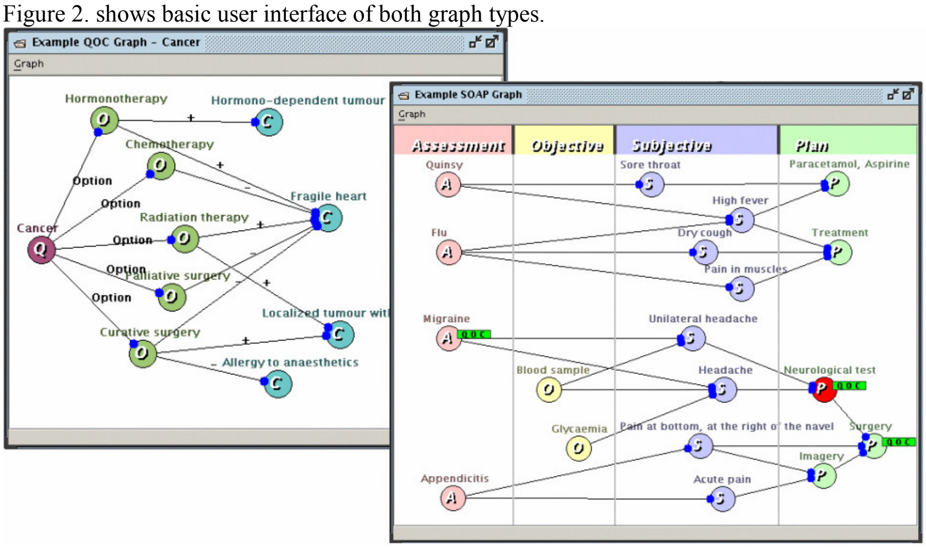

Fig. 2. Example of SOAP and QOC graphs

4. Architecture and Functions of the Virtual Staff

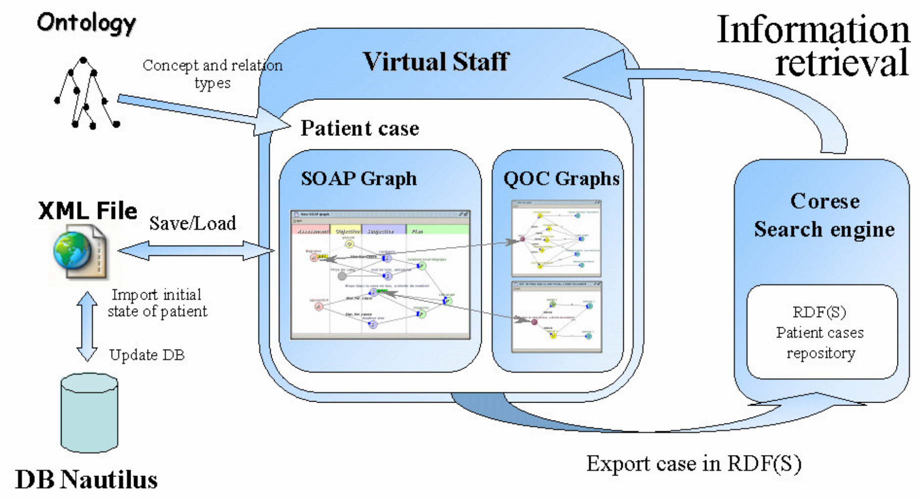

Fig. 3. Overview of Virtual Staff and its associated components

Virtual Staff (VS) is not a single stand-alone application. It is not either only a graphical editor and visualization tool of SOAP and QOC graphs. Besides VS, there are three other important components involved in preparation and reasoning of patient cases. First of all there is the Nautilus Database of electronic patient records (EPRs) serving as source of initial medical data for new patient cases.

To acquire consistent terminology and structure in graphs, nodes and arcs are connected with terms taken from ontology. First, the Nautilus DB had been transformed into RDF(S) [9] encoded ontology. Most of nodes and arcs in Virtual Staff are therefore associated with concept and relation types from this ontology. This also ensures compatibility of concepts used in both Nautilus DB/Episodus and Virtual Staff. Finally we need some tool for searching terms in the ontology. We choose CORESE search engine which enables information retrieval based on RDF(S) semantic annotations on documents or on persons [6]: CORESE can thus easily cooperate with Nautilus ontology. Whole context is described on fig. 3.

4.1. Nautilus DB of electronic patient records

Episodus, software of our industrial partner, offers management of electronic medical records stored in the Nautilus DB. Through Episodus, we could see the whole "life line" of given patient including evolution of all symptoms, diseases, treatments and other health care procedures (see fig. 1). It is useful to start a consultation with patient not with an "empty graph", but with a graph containing all mentioned items which are still active at the time of the consultation.

Hence we developed an exchange format for sending initial information about patient to Virtual Staff and possibly for later update of data in Nautilus DB according to acquired results. This format is written in XML and is fully compatible with Virtual Staff and the industrial partner is currently developing interface for Episodus to enable communication through this exchange format.

When a patient consults his/her doctor for new symptoms, the physician will create an instance of Virtual Staff. The system will then initialise a SOAP graph with all currently open pathologies and prescriptions for this patient, based on available information in XML file imported from Episodus. The initial A and P nodes automatically added in the graph correspond to the pathologies and the health care procedures already existing and open in the patient's life line.

4.2. Extended Nautilus Ontology

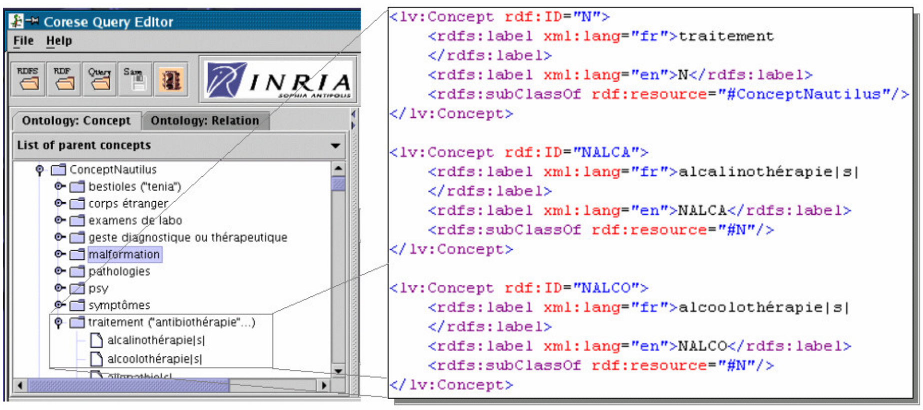

Fig. 4. Extract of Extended Nautilus Ontology

Extended Nautilus ontology was obtained from heterogeneous information sources (a database, a textual corpus, a classification). As it is represented in RDF(S), it can be directly accessed and queried by Corese Search engine (this was impossible with Nautilus DB conceptual schema). Advantage of this ontology is that graph nodes can be associated with concept types compatible with Nautilus DB. Without this compatibility it would not be possible to process initial import. Fig. 4. shows an extract of this ontology.

Just as nodes are associated with concept types, arcs should by associated with relation types. But as this ontology did not offer these relation types, it was necessary to enrich it with a minimum set of relations: *option* between question and option; *positive criteria*, *negative criteria* etc. between option and criterion, for QOC graphs. For SOAP graphs, some propositions should be refined after testing of Virtual Staff by doctors.

This also points to flexibility of Virtual Staff. Everything is taken from the ontology and no concept/relation type is hard-coded, so it is possible to switch to another ontology represented in RDF(S) without modifying source code.

4.3. Virtual Staff

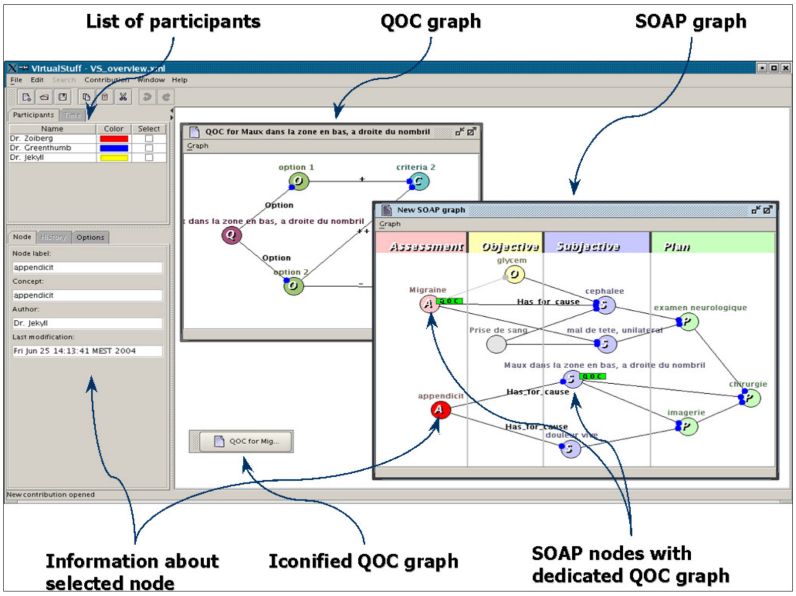

Fig. 5. Virtual Staff user interface

From the user point of view, Virtual Staff is a graphical editor of SOAP and QOC graphs, with possible connection of nodes and arcs with the ontology (through Corese search engine) and data interchange with Nautilus DB of EPR(s) (through XML interchange format).

Fig. 5 gives a general overview of Virtual Staff user interface. Main (right) part of window represents electronic board for creating and updating graphs. Left part gives us information about selected graph and node/arc, about all involved participants and about previous contributions. Selection of particular participant/contribution will enhance appropriate nodes with *color rings*. These *color rings* depend on to the contribution author, its role or the last modification time. This enables quick overview of which part of graph was created by which participant, at what time etc. Color enhancement could help new participant to better and faster understand patient case [2].

After brief examination of single case using these enhancements, the doctor should have sufficient information about case evolution and about reasoning of other participants.

It is possible to represent SOAP and QOC graphs through conceptual graphs [14], built by using the concepts and relations of the Nautilus ontology. Due to the correspondence between conceptual graphs and RDF(S) language [5][6][7], they can also be represented in RDF(S). Virtual Staff therefore implements another save function, this time using RDF(S) format. Through saving cases in RDF(S) we can obtain repository of closed/solved patient cases which could be later queried by Corese search engine or analysed by statistics and data-mining methods.

4.4. CORESE

CORESE (COnceptual REsource Search Engine) [5] [6] [7] is a semantic search engine dedicated to RDF(S) and is widely used within VS. Since the extended Nautilus ontology is represented in RDF(S) we can use Corese for finding requested concept and relation types. While adding or updating nodes in already existing part of the graph, the system can propose a list of possible concepts to help the user to build the SOAP and QOC graphs.

Another possible usage of Corese is querying of patient cases repository. We can query through Corese query language [7] questions like *"which **positive criteria** are in favour of **radiotherapy** option in QOC graphs for **cancer**"* or *"what is typical relation for two given concept types from Nautilus ontology"*. Answers to these questions could help the user in two ways. Firstly, they can serve as kind of a remainder, so that (s)he does not forget any option and/or criteria in QOC graphs and second, they can enable case-based reasoning while filling empty parts of graphs or making the QOC decision.

4.5. Data interchange between components using XML format

One of our assumptions is that any change in the graph must have a responsible participant. Each time a participant (any doctor or other medical person) opens new or already existing case, Virtual Staff automatically creates new *"contribution"* for this participant. Everything performed during this contribution (adding/changing nodes and relations) is stored in an XML file using *delta function* and for tractability reasons, it cannot be directly altered later.

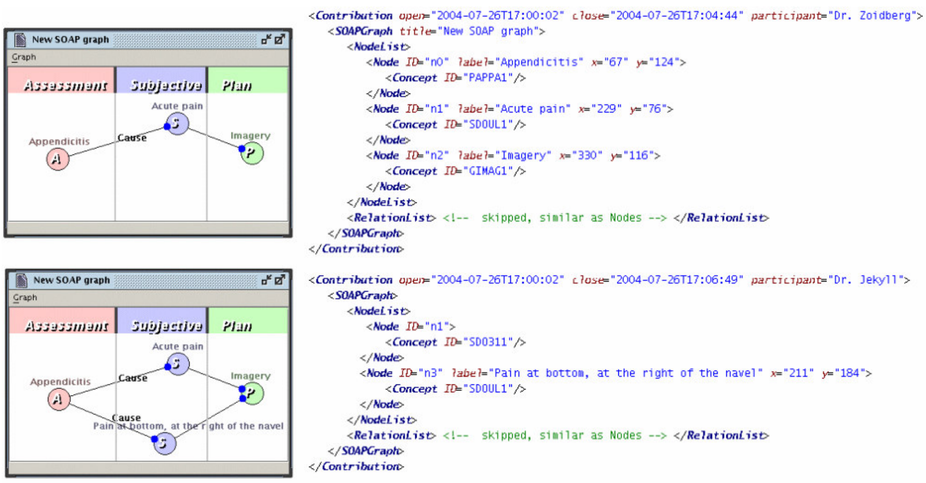

Fig. 6. XML format for storing cases using delta function

For example one doctor adds couple of nodes in SOAP graph and then closes his/her contribution. Then another doctor in a following contribution can modify these nodes and/or delete them, but Virtual Staff will remember both states, before and after modification. On the other hand, Virtual Staff cannot manage changes made within one contribution (e.g. when a doctor adds a new node and then removes it, nothing is stored in the delta function; if (s)he altered the name of some node several times, only the last value is stored etc.).

Fig. 6. presents two states of SOAP graph made by two consecutive contributions and shows the corresponding parts of XML file (for saving space we skip definition of relations between nodes). In first part is defined an initial state of SOAP graph, this means that every node and relation is stored. Whereas in second part there are only new nodes and modifications to existing nodes. This approach has several advantages. The user can easily find who is responsible for any part of any graph at any time, can backtrack to any previous contribution and see evolution of the patient's case and thanks to delta function, (s)he can also see whether some parts of graph were deleted and/or changed by different participants. For example from fig. 6, (s)he knows how the graph looks like and even more (s)he can see that Dr. Jekyll does not agree with Dr. Zoidberg in a particular part of graph. So it offers tractability on possible divergences between opinions of several doctors, with their respective arguments.

5. Cooperation using the Virtual Staff

Some patient cases are solved by a single doctor, but other complex cases need cooperation of several doctors having different medical specialties (in particular, in networks dedicated to heavy pathologies). Cooperation itself could be divided by time in *synchronous* and *asynchronous* and by place in *face-to-face* and *distant*. In ideal world, all cases will be solved in synchronous face-to-face sessions, but in practice doctors have to overcome "gaps" between places and time. While designing Virtual Staff, we had to take into account multi-user aspect with respect to all possible cooperation types.

Today it is easy to share XML or RDF(S) files, so the problem with distance between places is not the crucial one. No software tool can be sophisticated enough to fully replace natural collective discussion, but especially in medical domain, where there are many specialists and competence fields, it is difficult to get all required doctors in a same place at the same time. In Virtual Staff, it is possible to edit a patient's case asynchronously and members of health network can append their part of "knowledge" in the case at any time. Moreover Virtual Staff provides for new users valuable information about patient case history.

It is understandable that each specialist could have little bit different opinion on the same patient's case. After the patient's visit at a general practitioner, the doctor could for example prepare QOC graph for some new symptoms to diagnose. From his/her point of view (s)he makes general model of decision process using this graph according to his/her medical specialty. Then if another doctor e.g. cardiologist, examines the graph from viewpoint of his/her medical specialty, the graph could be enriched with new options and criteria and possibly with new decision of QOC. This process could continue iteratively for other relevant medical specialties.

If every participant is obliged to introduce his/her medical specialty on the VS (we call it *role of participant*) and as far as all graph states and decisions are saved using delta function, knowledge contained in graphs can be analysed from much more complex view. Searching history of patient case enables to see not only patient state for a given time, but it also brings us information about reasoning of all participants. In QOC graphs, the user can find out answers to questions like "*why and when particular treatment started*", "*which criteria were taken in account when treatment started*" etc. Each doctor could see which diseases and health care procedures were active during decision making and so on. If treatment failed for some reason and should be replaced (through a new QOC decision), then it is possible to list through all previous treatments and situations when these treatments were applied, and then to decide new treatment or to continue the older one (e.g. if new criteria recommending this treatment are given). So, Virtual Staff helps to visualize progress of all contributions and clearly shows reasoning of different participants.

6. Discussion

From organizational viewpoint, the organization constituted by a health care network can be considered as a virtual enterprise, with a rather informal structure, and its members constitute a community gathered by a common objective (i.e. offer the best health care and follow-up for the patients), each member having also more specific objectives due to his/her profession (e.g. doctor vs nurse vs social worker) and to his/medical specialty. The kind of cooperation in this organization may also depend on the kind of network: some networks are dedicated to a heavy pathology (e.g. diabetes, cancerology, etc), and will gather members from different professions and different specialties, while other networks will rather gather the same kind of health centers or of professionals (e.g. hospital professional network, liberal practitioner network, pharmacist network, nurse network, etc) and others will be dedicated to a type of patient (new born, old people). The kind of interactions will of course differ according to the type of network. Our approach, based on support to cooperative reasoning, seems useful for a healthcare network dedicated to a heavy pathology. In [1], four types of collaborative aspects in clinical research are emphasized: communication, sharing different records and material, planning of collaboration and collaborative problem solving: our approach tries to tackle at least patient record sharing and collaborative problem aspects

From cognitive viewpoint, the members of the network build themselves a mental representation of the patient's case. The graphs handled in the Virtual Staff aim at enabling a participant to visualize partly this representation, to share it with other participants and to make it evolve through cooperation with other participants. SOAP model seems relevant for medical reasoning and QOC for representing diagnosis and therapeutic decisions since QOC model is known as useful for design rationale of a design project: patient's health care and follow-up can be considered as a therapeutic project to which some members of the health care network will part in.

From technological viewpoint, in addition to SOAP and QOC graphs, we mainly rely on semantic Web technologies:

- ontologies for representing the concepts shared by the network members,
- RDF(S) for representation of ontology and annotations on the patient's record,
- Corese semantic search engine for querying the ontology and RDF annotations (in particular on one or several virtual staffs concerning one or several patients),
- XML for interchange between the virtual staff and the Episodus software describing the life time of the patient.

Our approach can be seen as tackling KM from several viewpoints:

- *Organizational memory:* we build a memory of a specific community constituted by the health care network members: these members may be individual or organizations (e.g; hospital, health centre). More precisely, we build a memory of health projects about patients: each life line of a patient is considered as the trace of a medical project, with events, phases, actors playing a role in this project. Tractability of the project decision rationale is tackled by QOC graphs.
- *Support to cooperative work:* our approach follows the suggestions of [13] for taking inspiration of CSCW for heath care support. We try to offer, in a longer-term, shared understanding, informed participation and social creativity, as in the vision of Fischer [8].
- *Case-Based reasoning*: even though we do not use classic Case-Based Reasoning techniques [11], querying through Corese on past patient cases and past VS sessions in order to have suggestions for a new patient case aims at the same objective as case-based reasoning.

7. Conclusions

In this paper, we presented software tool called Virtual Staff enabling members of a health care network to create, modify, consult alone or together: SOAP graphs describing the links between diagnostic and therapeutic hypotheses, symptoms and observations, and QOC graphs for support to decision-making. The nodes of both kinds of graphs are typed by the concepts of the Nautilus ontology. Such a combination of these SOAP and QOC models with an ontology is original and illustrates the interest of an ontology to help the user to visualize a reasoning or a decision-making process.

Virtual Staff is also designed for multi-user cooperative work with possible backtracking through evolution of cases. This enables to see how knowledge contained in graphs was modelled and how reasoning and decision making were processed. Solved and closed cases are stored in RDF(S) repository and they can be analysed to get new knowledge (to improve ontology etc.) or reused in case-based reasoning on new cases.

To reach platform-independence Virtual Staff is completely implemented in JAVA. Connection to Nautilus DB or other database of EPR(s) is optional, but to run Virtual Staff, the user needs to rely on an ontology represented in RDF(S).

The first version of the Virtual Staff was validated by the industrial partner, from two viewpoints: its functions and its interfaces. This evaluation led to several improvements of the graphical interface of the virtual staff: the new interface - illustrated by the figures through the paper - helps the user to really follow the reasoning guided by the SOAP model (each part of the graph is dedicated to nodes expressing either an Assessment or an Objective or a Subjective or a Plan) or by the QOC model (Question → Option → Criterion). We will also ask actual physicians to handle the Virtual Staff in order to evaluate it from the viewpoint of a real end-user.

The Nautilus ontology and the Virtual Staff were validated by Nautilus society. Notice that, even though the Virtual Staff was implemented with the Nautilus ontology (for collaboration reasons), it would be possible to adapt the Virtual Staff to another medical ontology such as UMLS meta-thesaurus [12].

As IBIS method is close to QOC method, we can compare the virtual staff to gIBIS [4], that already relies on graph visualization, and offers argumentation on decisions. But our originality is to combine both SOAP graphs and QOC graphs and to rely on a medical ontology for building and handling these graphs. Another cooperative tool for a healthcare network is WebOnColl [3], a web-based medical collaborative environment relying on user profiles and virtual workspaces.

As a further work, the industrial partner will proceed to end-user focused evaluation by physicians taking part in an actual network (probably in diabetes).

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