Achieving Competence by Argumentation on Rules for Roles

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Abstract. We consider the deep venous thrombosis (DVT) as case study for the specification and implementation of a multi-agent system. The DVT is an application with low clinical accuracy, needing objective tests, some of them satisfactorily accurate in experienced hands and others more definite but invasive. Whether one or more decision makers are involved in this activity is a matter of context, but the main events are decided by a process that has in itself some forms of argumentation. Our approach is an argumentative multi-agent system specified by rules capturing various roles in the diagnosis activity. Although the DVT scenario is a real one, more aspects of health care than the ones presented in this paper can conveniently be accommodated in this framework by extending the set of roles and refining the set of rules.

1 Introduction

There are many situations in the medical setting when conflicts of opinion may appear between different care providers, each judging the situation based on its own knowledge and duty. Consider the case of a patient that has just been diagnosed; there are several possible treatments given the diagnosis and a choice must be made among those treatments. Different care providers may have different opinions about the optimal treatment based on their role and expertise. Still, a decision has to be made based on their possible contrary opinions. Another point of divergence between medical professionals may be the investigations that are more appropriate to perform for establishing a diagnosis. Some investigations are cheaper, while others may be less harmful to the patient.

Although sometimes it is possible to make decisions in diagnosis taking into account just the information available [1], in the cases considered above several roles are involved in the medical decision process, a choice having to be made between the possible conflicting opinions of each role. Additional information may be needed for making that choice, due to the multiple options available.

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Automated monitoring of medical protocols has been already tackled with a multi-agent system [2], using a negotiation process to mediate between multiple medical protocols, where role refers to a particular service that can be played by a staff person. A multi-agent environment to support training of diagnostic reasoning and modeling of domains with complex and uncertain knowledge [3] uses Bayesian networks to offer physicians probabilistic reasoning.

The framework described in this paper aims to help automate/model the decision making between different roles that are involved in the medical care process by making use of the knowledge base of each role and also by additional knowledge needed to solve conflicts of opinion between roles. Recent work [4, 5] is used to develop a more flexible methodology required by realistic applications in the health providing activity. The particular contributions of this paper are threefold: first, we provide a realistic motivating scenario which is quite pervasive in the health providing world; second, we show how a role specified by rules can be combined with one based on experience; third, we show how experience made public in the Web Ontology Language is used in the argumentation process.

The paper is organized as follows. Next the basic argumentation framework [4, 5] is summarily presented. Then the DVT scenario is explained in terms of rules used by the physicians [6] and results obtained from a controlled trial [7]. Two roles extracted from [6, 7] are then derived as *AIM98Agent* and *NEJM03Agent*, and their interaction by argumentation is portrayed. After a brief description of the implementation and related work some conclusions are drawn.

2 Basic Argumentation Framework

We are using the reasoning in an argumentative manner provided by Gorgias[1] [4, 5], to determine the case in a certain context. Following the example found in the Gorgias package on the agent wanting to find out if its security interest in a certain ship (i) is perfected (c), it currently has possession (p) of the ship, and according to the "Uniform Commercial Code" (u) a security interest in goods may be perfected. According to the federal law "Ship Mortgage Act" (m) a security interest in a ship may only be perfected by filing a financing statement (e). These are the rules used to determine whether the security interest is perfected or not.

$$Rules = \left\{ \begin{array}{l} u : c \leftarrow p \\ m : \neg c \leftarrow i, \neg e \end{array} \right\}$$

In this example, other facts are: a statement has not been filed ($\neg e$), the "Uniform Commercial Code" (u) is newer than the "Ship Mortgage Act" (m), with the later a federal act, and the former a state act.

[1] http://www.cs.ac.cy/~nkd/gorgias

$$\begin{tikzcd}
 & D : [\neg c; m, f2, f3] & \\
A : [f4, post(u,m), f1, u; E_1] \arrow[ur, "\neg a"] & & A : [f4, post(u,m), f1, u; E_2] \arrow[ul, "\neg a"'] \\
D : [f6, f5, sup(u,m); E_1] \arrow[u, "a"] & & D : [f6, f5, sup(u,m); E_2] \arrow[u, "a"]
\end{tikzcd}$$

Fig. 1. Defender/attacker argumentation tree

$$Facts = \left\{ \begin{array}{l} f1 : p \\ f2 : i \\ f3 : \neg e \\ f4 : n(u,m) \\ f5 : f(m) \\ f6 : s(u) \end{array} \right\}$$

There are two principles expressing contexts: one is the "Lex Posterior", which gives precedence to newer laws (u is newer than m), and the other is the "Lex Superior", which gives precedence to laws supported by the higher authority (m has higher authority since it is a federal law).

$$Contexts = \left\{ \begin{array}{l} post(X,Y) : X \prec Y \leftarrow n(X,Y) \\ sup(X,Y) : Y \prec X \leftarrow s(X), f(Y) \\ cpr : sup(X,Y) \prec post(X,Y) \end{array} \right\}$$

The proof tree for $[\neg c]$ is shown in the figure 1, where a node is marked with D for defendant or A for attacker. The two extensions used are E_1=$\{f2, f3, m\}$ and E_1=$\{f2, f3, f5, f6, sup(u,m)\}$.

3 Deep Venous Thrombosis Scenario

Deep venous thrombosis (DVT) could be defined as the presence of an occlusive thrombus (clot) within a deep vein, impairing the normal blood flow. Deep venous thromboses occur most commonly in the lower extremities, and half cause pulmonary emboli (the most severe complication of DVT) in the absence of treatment. A familial or a personal history of prior DVT and the hypercoagulation states: antithrombin III deficiency, antiphospholipidic syndrome, polycytaemia vera, thrombocytemia, ... are major *predisposing risk factors*. Patients particularly prone to the development of DVT are also those who are seriously ill and have been at bed rest for prolonged periods. Some of the patients who are at highest risk are those who have congestive heart failure, stroke, recent myocardial infarction, malignancies, pelvic /abdominal surgery, especially orthopedic procedures, trauma - particularly with prolonged immobilization. In addition, persons more than 60 years old have an increased incidence of DVT, as do obese persons, patients with varicose veins, users of contraceptives or high-dose estrogen therapy. Pregnancy and the period following childbirth favor DVT. Long journeys, venous compression, venous catheter insertion or injections might favor DVT in the presence of other risk factors.

Episodes of DVT are often *clinically* silent, therefore a high level of suspicion is necessary. Pretest assessment of the probability of DVT is useful (i.e. evaluation of predisposing factors or conditions) when deciding the investigations required to establish diagnosis. History and physical examination are neither sensitive nor specific for diagnosis. The presence of symptoms or signs as pain or edema is not sufficient for diagnosis and implies the need for objective diagnostic testing. The objective testing is crucial, because undiagnosed DVT can cause fatal pulmonary embolism, and because of DVT therapy is effective, but its inappropriate use should be avoided. Clinical suspicion may dictate the speed and type of evaluation.

Among the *objective tests*, the serum level of D-dimers (established by ELISA) has a high sensitivity (>95%), a lower specificity and a high negative predictive value. A positive test makes DVT probable, but requires further evaluation; a negative test excludes with high probability DVT. Venous ultrasonography, combined with Doppler, is satisfactorily accurate in experienced hands, readily available, non-invasive and repeatable. Impedance plethysmography is non-invasive, safe, but useful especially for diagnosing proximal DVT in symptomatic patients. Its performances are increased when associated with other noninvasive tests. Contrast venography is the reference ("gold") standard for the diagnosis of DVT, being the most definitive diagnostic test, but it is an invasive examination, associated with risks for the patient and high technical demands and costs. Therefore, investigation using non-invasive ultrasound techniques in combination with the D-dimer test is often regarded as sufficient in symptomatic patients with suspected DVT.

3.1 Rules for Diagnosis

The findings that are diagnostic of DVT (see [6]) can be expressed by the rules shown in the figure 2 (with a rule of grade A stronger than one of grade B and one of grade B stronger than one of grade C). The first two rules say that

$$
\begin{aligned}
&diagDVT(grA) \leftarrow ultrasonography(commonFemoral) \vee ultrasonography(popliteal)\\
&diagDVT(grB) \leftarrow ultrasonography(superficialFemoral)\\
&\qquad\qquad\qquad\quad \vee ultrasonography(distalPopliteal) \vee ultrasonography(deepCalf)\\
&diagDVT(grA) \leftarrow plethysmography(abnormal), clinical(high)\\
&diagDVT(grB) \leftarrow plethysmography(abnormal), (clinical(moderate) \vee clinical(low))\\
&diagDVT(grA) \leftarrow venography(defect)\\
&diagDVT(grC) \leftarrow venography(suggestive)
\end{aligned}
$$

Fig. 2. Rules that are diagnostic of DVT

$$exclDVT(grA) \leftarrow venography(normal)$$
$$exclDVT(grA) \leftarrow ultrasonography(normal), clinical(low)$$
$$exclDVT(grC) \leftarrow ultrasonography(normal), dDimer(normal)$$
$$exclDVT(grB) \leftarrow plethysmography(normal), dDimer(normal)$$

Fig. 3. Rules that exclude DVT

$$venography \leftarrow ultrasonography(superficialFemoral) \vee ultrasonography(distalPopliteal) \vee ultrasonography(deepCalf)$$
$$ultrasonography \leftarrow plethysmography(abnormal), (clinical(moderate) \vee clinical(low))$$
$$venography \leftarrow plethysmography(abnormal), (clinical(moderate) \vee clinical(low))$$
$$ultrasonography \leftarrow venography(suggestive)$$
$$plethysmography \leftarrow venography(suggestive)$$
$$clinical \leftarrow venography(suggestive)$$

Fig. 4. Rules recommending examinations

venous ultrasonography shows DVT in the case of non-compressibility of the common femoral vein or popliteal vein (grade A), while non-compressibility that is confined to the superficial femoral vein, the distal portion of the popliteal vein, or the deep veins of the calf is associated with a lower predictive value (grade B). The following two rules express that impedance plethysmography shows DVT in the case of an abnormal result and a high clinical suspicion of deep venous thrombosis (grade A), while an abnormal result of impedance plethysmography combined with a moderate or low clinical suspicion of DVT has lower predictive value (grade B). The last two rules on venography say that an intraluminal filling defect seen in more than one view are diagnostic of DVT (grade A), while onfilling of the deep veins despite repeated injection of contrast, are just highly suggestive of DVT (grade C).

Findings of the group of experts that exclude DVT (see [6]) include the rules shown in the figure 3. The first rule says that a normal result of venography excludes DVT (grade A). A normal ultrasonography and (i) low clinical suspicion of DVT (grade A) or (ii) a normal result on a D-dimer assay (grade C) are shown by the following two rules to exclude DVT. A normal result on impedance plethysmography and a D-dimer assay (grade B) exclude DVT as shown by the last rule.

The recommendations for the diagnosis of DVT (see [6]) also include the rules for investigations shown in the figure 4. Non-compressibility that is confined to the superficial femoral vein, the distal portion of the popliteal vein, or the deep veins of the calf should be evaluated with venography (first rule). An abnormal result of impedance plethysmography combined with a moderate or low clinical suspicion of deep venous thrombosis should be evaluated with venous ultrasonography or venography (second and third rule). Nonfilling of the deep veins despite repeated injection of contrast (highly suggestive of DVT), must be interpreted in the light of clinical presentation and other investigations, such as results of impedance plethysmography or venous ultrasonography (the last three rules).

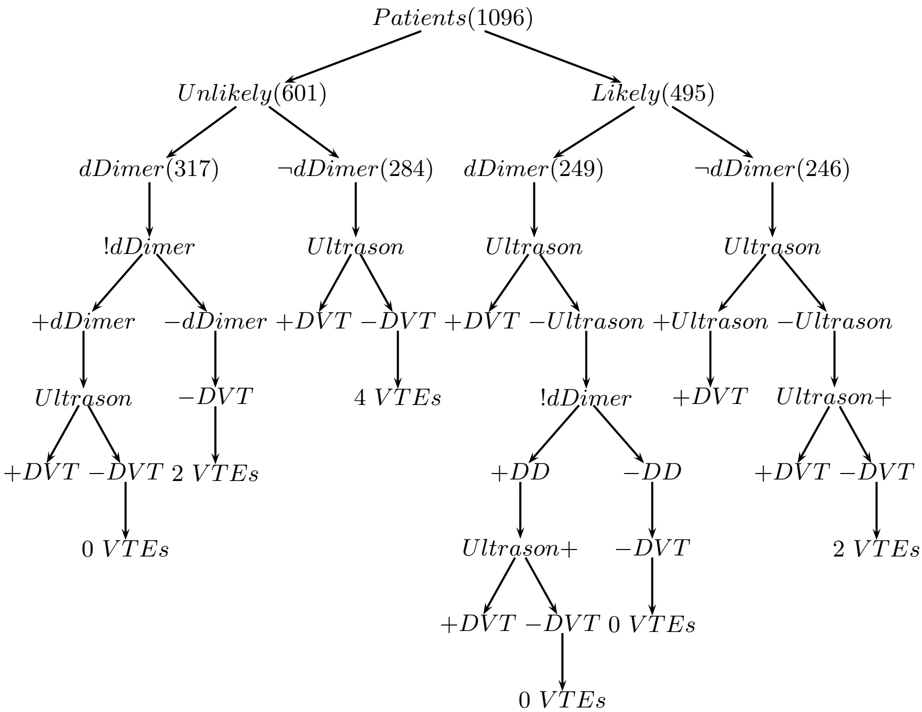

Fig. 5. Patient outcomes in the evaluation trial

3.2 Controlled Trials

An evaluation of D-dimer in the diagnosis of suspected DVT [7] has concluded that DVT can be ruled out in a patient who is judged clinically unlikely to have DVT and who has a negative D-dimer test, and therefore ultrasound testing can be safely omitted in such patients.

The results of this controlled trial are shown in the figure 5 (see [7]). All patients were first evaluated using a clinical model and divided into two groups considered (clinically) unlikely or likely to have DVT. They were then randomly assigned either to undergo ultrasound imaging alone (control group) or to undergo D-dimer testing. Those in the later group then underwent ultrasound imaging (Ultrason) if they had been judged clinically likely to have DVT or if they were judged clinically unlikely but the D-dimer test (!DD) was positive (+DD).

The primary outcome of this evaluation was the development of a venous thrombo-embolic event (VTE) in patients in whom DVT had initially been ruled out. They offer histories for re-evaluating the diagnosis model or, as we consider here, knowledge for an evaluation agent that can also provide cues for argumentation to the diagnosing agent. For example, we can see that there were two patients judged clinically unlikely who, with a negative D-dimer test (–DD), DVT was ruled out (–DVT) but still developed a venous thrombo-embolic event (2 VTE). For the patients judged clinically likely a second ultrasound imaging

(Ultrason+) was performed after one week, which helped to reduce risk in the group with the D-dimer test.

4 Argumentation with Rules for Roles

The diagnosis process takes place on a time line and can be visualized as in the figure 6. In the state s_i the agents know the history H of the diagnosis process

$$\underbrace{s_0 a_0 s_1 \ldots a_{i-1}}_{\substack{H \\ \downarrow \\ \text{past}}} \; s_i \; \underbrace{a_i s_{i+1} \ldots s_{n-1} a_{n-1} s_n}_{\substack{F \\ \downarrow \\ \text{future}}}$$

Fig. 6. Course of action

for the patient and have to decide about the future F, the remaining course of actions so that the proper conclusion is reached. That means that the patient will finally be diagnosed either as +DVT and the corresponding treatment will be applied or –DVT and no VTE event should occur in a reasonable period (three months in the controlled trial).

A state of a patient is represented by the results of the investigative actions. For example, $\{-c_0, +d_1, -u_2\}$ shows the state of the patients judged clinically unlikely with a positive D-dimer test and a negative ultrasonography investigation, which should have been ruled out for DVT. The patients with the state $\{+c_0, -u_1, -u_2\}$ have been ruled out for DVT in the evaluation but two of them have developed VTE (see figure 5).

4.1 The AIM98Agent Role [6]

The set of preferences over actions in the DVT scenario, regardless of context, is $\{c \prec v, c \prec u, c \prec p, c \prec d, u \prec v, p \prec v, d \prec v, d \prec u\}$, that is *clinical* examination is preferred to *venography*, ..., D-dimer is preferred to *ultrasonography*. The preferences on diagnostic rules are:

$$gr_0 : d(A) \prec d(B) \tag{1}$$
$$gr_1 : d(A) \prec d(C) \tag{2}$$
$$gr_2 : d(B) \prec d(C) \tag{3}$$

Our rules that are diagnostic of DVT in the state s_i are transformed from the diagnostic rules of the group of experts discussed previously and shown in the figure 2.

$$d_0 : dvt(A) \leftarrow u(cF) \in s_i \vee u(p) \in s_i \tag{4}$$
$$d_1 : dvt(B) \leftarrow u(sF) \in s_i \vee u(dP) \in s_i \vee u(dC) \in s_i \tag{5}$$
$$d_2 : dvt(A) \leftarrow p(a) \in s_i \wedge c(h) \in s_i \tag{6}$$
$$d_3 : dvt(B) \leftarrow p(a) \in s_i \wedge (c(m) \in s_i \vee c(l) \in s_i) \tag{7}$$

$$d_4 : dvt(A) \leftarrow v(d) \in s_i \tag{8}$$
$$d_5 : dvt(C) \leftarrow v(s) \in s_i \tag{9}$$

while those that exclude DVT are the transformation of the the rules of experts shown in the figure 3.

$$e_0 : \neg dvt(A) \leftarrow v(n) \in s_i \wedge c(l) \in s_i \tag{10}$$
$$e_1 : \neg dvt(C) \leftarrow dd(n) \in s_i \tag{11}$$
$$e_2 : \neg dvt(A) \leftarrow p(n) \in s_i \wedge dd(n) \in s_i \tag{12}$$

The rules recommending an action a_i are in the state s_i include the rules for investigations recommended by experts and shown in the figure 4.

$$a_0 : v(A) \leftarrow u(sF) \in s_i \vee u(dP) \in s_i \vee u(dC) \in s_i \tag{13}$$
$$a_1 : u(B) \leftarrow p(a) \in s_i \wedge (c(m) \in s_i \vee c(l) \in s_i) \tag{14}$$
$$a_2 : v(A) \leftarrow p(a) \in s_i \wedge (c(m) \in s_i \vee c(l) \in s_i) \tag{15}$$
$$a_3 : u(B) \leftarrow v(s) \in s_i \tag{16}$$
$$a_4 : p(A) \leftarrow v(s) \in s_i \tag{17}$$
$$a_5 : c(C) \leftarrow v(s) \in s_i \tag{18}$$

If preferable, we can use rules showing preferences over actions in a given context,

$$c_0 : u \prec v \leftarrow p(a) \in s_i \wedge (c(m) \in s_i \vee c(l) \in s_i) \tag{19}$$
$$c_1 : d \prec u \leftarrow v(s) \in s_i \tag{20}$$

that is ultrasonography is preferred to venography when plethysmography is abnormal and clinical assessment is medium or low, and D-dimer is preferred to ultrasonography when venography is suggestive.

4.2 The NEJM03Agent Role [7]

We use the Web Ontology Language (OWL)[2] to represent ontologies, developed and accessed in the SWI Prolog tool Triple. For instance, an excerpt of the OWL representation of the patient outcomes in the evaluation trial (figure 5) are shown in the figure 7. The rules are also made available to various agents, when public, in OWL with a proper encoding.

An NEJM03Agent has access to the controlled trial histories and is capable to extract a history like

$$\underbrace{\{c(l)_0\}}_{s_0}\underbrace{u_1}_{a_1}\underbrace{\{c(l)_0, u(n)_1\}}_{s_1}\underbrace{\neg dvt}_{a_2}\underbrace{\{c(l)_0, u(n)_1, \neg dvt\}}_{s_2}\underbrace{w}_{a_3}\underbrace{\{c(l)_0, u(n)_1, \neg dvt, VTE\}}_{s_3}$$

[2] http://www.w3.org/TR/2004/REC-owl-ref-20040210/

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Fig. 7. Excerpt of the evaluation trial in OWL

showing that out of 601 patients found clinically unlikely to have VDT after a normal ultrasonography test on 284 of them the decision (action) has been made that they do not have VDT. But still, after a period of waiting, four of them have developed VTEs.

Another path this agent can extract from the tree of the controlled trial is

$$\underbrace{\{c(h)_0\}}_{s_0}\underbrace{u_1}_{a_1}\underbrace{\{c(h)_0, u(n)_1\}}_{s_1}\underbrace{w(1)_2}_{a_2}\underbrace{\{c(h)_0, u(n)_1, w(1)_2\}}_{s_2}\underbrace{u_3}_{a_3}\underbrace{\{c(h)_0, u(n)_1, w(1)_2, u(n)_3\}}_{s_3}$$

$$\underbrace{\{c(h)_0, u(n)_1, w(1)_2, u(n)_3\}}_{s_3}\underbrace{\neg dvt}_{a_4}\underbrace{\{c(h)_0, u(n)_1, \neg dvt\}}_{s_4}\underbrace{w}_{a_5}\underbrace{\{c(h)_0, u(n)_1, \neg dvt, VTE\}}_{s_5}$$

showing that out of 495 patients found clinically likely to have VDT after two normal ultrasonography consecutive tests on 246 the decision has been made that they do not have VDT. After a period of waiting, two of them have developed

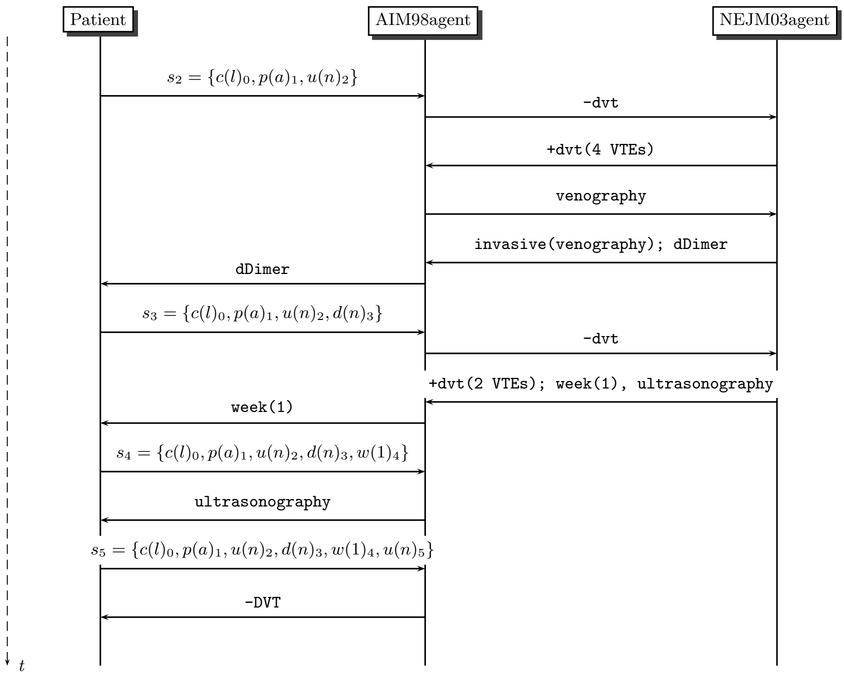

Fig. 8. Sequence diagram illustrating argumentation

VTEs. These histories are exploited by the NEJM03Agent to argue on whether a course of action might be successful or not to attain the goal of either diagnosing the patient as having DVT (to be treated) or not, but without incurring the risk of a VTE.

4.3 Argumentation on DVT Diagnosis

Let us consider the case of a patient judged clinically low to which a plethysmography test revealed abnormality, while the ultrasonography has shown a normal case as shown in the figure 8. The AIM98Agent is tempted to decide no DVT, but to make sure is requesting the NEJM03Agent's opinion about it. The NEJM03Agent retrieves from its OWL controlled trial history four such cases that have later developed VTEs, and therefore cannot accept this decision. The AIM98Agent proposes venography, but then NEJM03Agent replies that it is invasive and proposes instead d-Dimer, to which AIM98Agent agrees. The tree showing this process of argumentation is depicted in the figure 9.

Now in situation s_3, the AIM98Agent decides no DVT, letting NEJM03Agent know about the new proposal. Again, NEJM03 disagrees, this time mentioning two such cases in its historical representation of the controlled trial, and proposing instead ultrasonography after one week. The AIM98Agent agrees and

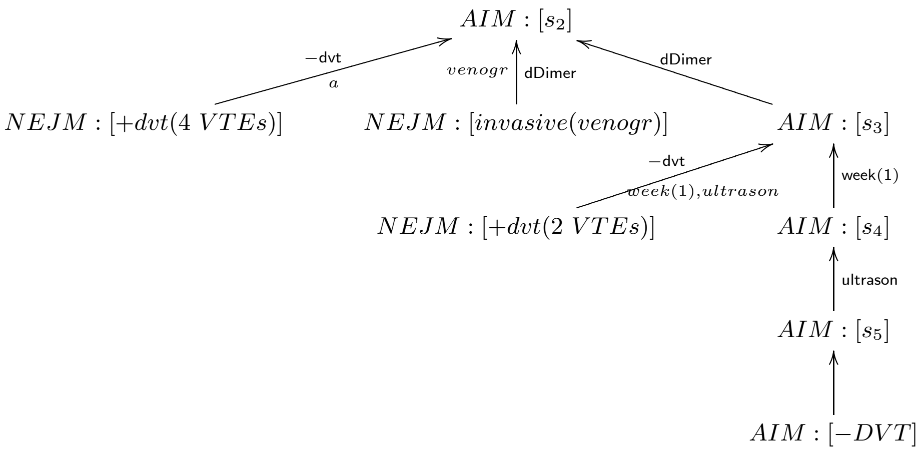

Fig. 9. Sample argumentation tree between the AIM98Agent and the NEJM03Agent

requests the patient to come back after one week and have ultrasonography. On the new state s_5 it decides that the patient does not have DVT.

5 Implementation

The current implementation of the system is in the Open Agent Architecture (OAA)[3]. For each user agent a solvable is defined which is called by the coordinator agent whenever a new reasoning step is performed. The AIM98Agent and the NEJM03Agent are implemented as user agents, defined via solvables through which the coordinator agent can announce them of the opportunity to perform an action or of a decision that has been taken that concerns them.

Other rules are introduced in the system that express the common sense reasoning, which is not expressed in the rules (4 - 18) extracted from the experts in the domain. For instance, rule (21) says that we prefer rule a_2 to rule a_1 when the current course of action is over a certain length k.

$$c_2 : a_2 \prec a_1 \leftarrow i > k \tag{21}$$

The rules for the protocol are similar to the ones in [8], in order to provide more flexibility to the interaction between the agents involved in argumentation.

$$p_0 : tell(Y, X, accept, D) \leftarrow tell(X, Y, propose, D) \wedge \neg counterArg(Y, D) \tag{22}$$
$$p_1 : tell(Y, X, reject, D, D1) \leftarrow tell(X, Y, propose, D) \wedge counterArg(Y, D, D1) \tag{23}$$

Here, p_0 states the accepting alternative, when agent Y has no counterargument to the proposal D of X. The rule p_1 is used by Y when it does not agree with

[3] http://www.ai.sri.com/˜oaa/

the proposal D of X and shows its counterargument and, eventually, another alternative for action in $D1$.

These rules allow more refinement, particularly important when the agents performing the diagnosis have to face various patients with quite different health history. We also did not consider here the asymptomatic or the recurrent version of DVT [6], which require a more complex dialog between the AIM98 and NEJM03 agents.

6 Related Work

The system for the assistance and supervision of the real-time application of medical protocols presented in [2] is based on the specification by medical protocols of possible sequences of composite, concurrent and repeated actions. In this system the roles specify particular services and medical protocols specify possible interactions between medical services. It is suggested that it can be used to manage both medical guidelines and medical protocols. Our proposal of roles offers more flexibility, in the sense that the behavior of the agents is specified by medical rules and other rules that take into account the context.

The AMPLIA multi-agent intelligent learning environment [3] is designed to support training of diagnostic reasoning and modeling of domains with complex and uncertain knowledge. The system deals with uncertainty using Bayesian networks. Used in the training of medical students, the qualitative and quantitative model built by the learning student is compared with the one provided by a domain expert. The interaction between the domain agent and the learner agent is performed according to an interaction protocol. While our system can be further developed to allow medical students to learn the process of diagnosis, the representation of medical knowledge by rules seems to be more acceptable to human agents and therefore our alternative would provide a significant advantage.

The integration of medical services [11] aims to ease the communication and provide meaningful transformation among distributed and heterogeneous applications. An intelligent broker transforms a client request of a valid high level service into several elementary steps. For each step a specific agent is used to realize the operation configured in the step. The mapping among different vocabularies is done by a semantic component using XML as the interchange format. Our framework has the capability to cover both the contexts that appear in such an application and the communication in OWL which is defined on top of XML may accept a shared ontology or even several ontologies.

The argumentation framework based on the language $\mathcal{E}$ [9] uses a basic ontology of actions, fluents and time-points inspired by the event calculus. We intend to further develop our system to take advantage of the benefits offered by the event calculus.

The PARMA protocol [10] permits argument over proposals for actions, enabling participants to rationally propose, attack, and defend, an action or course of actions. The basic protocol in our system can easily be developed to cover more complex interactions between agents.

A conversation moderator [12] has been devised to guarantee that the shared objectives in the conversation between participants will be observed. The solution of dissociating the *strategic* dimension from the *tactical* dimension in the application of protocol rules has the benefit of defining the role of the conversing agent (concerning strategy) and the role of the moderator (concerning tactics). This line seems to be very convenient to be pursued in the development of our system.

7 Conclusions

Our prototype implementation of argumentation has shown the convenience to extend the scenario of DVT with symptoms caused by different diseases. Thus, given a patient which presents a set of symptoms different specialists with different areas of expertise may draw different conclusions about the disease the patient is suffering of. Controversies may also appear in the medical setting between the medical staff and the administrative personnel. For example, while the main concern of a physician is the healthy state of the patient, the administrative personnel is more concerned with available resources.

Although work on argumentation in negotiation [13] seems to be quite advanced, the roles imposed in some activities in the applications that we envisaged require more cooperation, even if argumentation is a significant instrument in such contexts. In this respect the approach considered in this paper, with application to the health providing service, but also other services, is more in line with the fault-tolerant multi-agent systems by assigning missing roles [14], as the main objective is the quality of the service provided to customers. Viewed as a collective human work activity, a future evaluation of our framework will consider performance through the coordination enabled by the activity theory [15].

Since our main goal is in advising human agents in their decisions on acting in the real world our next step in this line of research will be on how argumentation on the acts could be further refined to better capture their effects on agents' objectives [16]. Ideas of the domino agent model and the PROforma language will be considered for representation in a future development of our argumentation scheme [17]. We are also interested in finding out how electronic institutions [18] can contribute to better model/automate argumentation processes in more realistic applications. To enable comparison with well known and deployed architectures like dMARS we will also develop a specification using the Z notation [19].

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