Using Case-Based Reasoning for Argumentation with Multiple Viewpoints

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Abstract. The integration of classical case-based reasoning with other problem solving methods attracts increasing research interest in the broader area of information and decision support systems. This paper presents a framework where CBR and Argumentation Based Reasoning jointly aid agents to address various discourse instances in group decision making processes. The ability to comprehend and engage in arguments is essential for these environments, while use of precedent cases is well-suited. Cases in our model are not merely considered as representations of past data, but as flexible entities associated with the underlying *view-point* of an agent and the *evolution* of the corresponding discussion. The paper provides an object-oriented description of the elements involved, and illustrates their dependencies through a comprehensive example.

1 Introduction

Group decision making and planning environments are usually characterized by multiple goals and diverse interests, depending on the points of view of the agents involved. In order to reach understanding, negotiate and resolve conflicts, agents may use various types of knowledge to warrant their arguments towards the selection or rejection of a statement or action. In such domains, case-based reasoning and learning techniques have been particularly useful [14], due to their resemblance to the way people evaluate a potential future action by using past experience, the scarcity (or even absence) of explicitly stated rules, and the ill-structured definitions of the associated problems [1]. On the other hand, mainly stemming from legal reasoning procedures, argumentation has become an appropriate means of interaction in such environments, because it provides agents a means of handling incomplete, uncertain and inconsistent information and accommodating the different methods of expressing and evaluating knowledge they use [7], [18].

This paper deals with the integration of CBR with Argumentation Based Reasoning. The involvement of numerous participants from different contexts (e.g., resource managers, designers, politicians, citizen groups, etc.) in a discussion implies the presence of various selection criteria, preferences, goals etc. We address this issue by explicitly specifying the notion of *viewpoints*. According to our approach, agents involved in a discussion make their viewpoints transparent to the others. Argumentation is performed by various discourse acts aiming at challenging an opponent's opinion. Viewpoints are not static, but may evolve upon time, under the presence of new information or appropriate retrieved cases. Integration of CBR techniques aims at supporting agents involved in group decision making processes to retrieve, adapt and re-use old cases. We view cases not merely as representations of past data, but as flexible entities that can be filtered according to the viewpoint of an agent and the episode of the corresponding discussion (i.e., previous instances of the related argumentation graph), as it has evolved over time.

Previous research has (mostly implicitly) addressed only parts of our approach. For instance, focusing on the legal domain, BankXX system [16] retrieves previous cases and other domain knowledge in support of an argument. In this approach, an argument consists of a set of *argument pieces* representing appropriate fragments of legal knowledge, but as admitted, the corresponding "idealization" of arguments does not reflect the logical and rhetorical connections between the various pieces of an argument. The integration of case and rule based reasoning paradigms, in order to construct an argument to support a particular interpretation of an agent, is also addressed in CABARET system [15]. The concept of viewpoint is involved in the system in a narrow way: one uses cases in order to determine whether the new case is *in* or *out* of the category of the predicate (citing [15], the system supports only *pro* and *con* points of view).

The majority of CBR applications views cases as instances of a standardised template. This results to a considerable reduction of the computational cost involved for the indexing, matching and retrieval processes, but reduces the flexibility and efficiency of the system. Consideration of cases as *virtual views* of the underlying data is proposed in [6]. Actually, this approach involves population of a case base by *mappings* attached to a standardised case format; in such a way, cases are only indirectly linked to the data on which they are based. *Re-interpretation* and *adaptation* of cases in the presence of new input are jointly considered in [8], the distinction among them being at the level which a case description has to be modified. Re-interpretation of a case is meant to be a "look" from a new point of view, and is associated with a new high-level description of it, while keeping the same low-level one; on the other hand, adaptation of a case relates to the change of both its high-level and low-level descriptions. This can be translated to giving a case-based system the ability to create its own dimensions in response to an input problem. In our framework, agents are the ones that decide the dimensions of a case in order to force its retrieval. However, we also follow a similar approach concerning conceptualised representation of cases at different levels.

Addressing the needs of agents to integrate reasoning with cases, reasons and underlying argumentation principles, TRUTH-TELLER [4] compares pairs of cases (presenting ethical dilemmas about whether to tell the truth), and generates a comparison text contrasting the reasons in each case. Even if the program does not retrieve and select relevant precedent cases in order to analyze problematic instances (like in traditional and our approach), the approach is interesting and in line with our goals, in that it explicitly involves in a case the salient reasons for its overall assessment (for more on the role of the general knowledge in providing explanatory support to the case-based processes, see [2], [12]).

Sycara's PERSUADER functions as a mediator in hypothetical labor negotiations. Given such a dispute, the program suggests an appropriate settlement (compromise) to the disputants. If this is rejected, PERSUADER tries to modify either the settlement (by CBR and preference analysis methods) or the opposing party's view (through persuasive argumentation). Our approach addresses the wider area of argumentative discourses; all discourse acts are performed by the agents involved in a discussion.

Finally, the dynamic aspect of our approach in the consideration of cases has been addressed in [3], where case retrieval performance is shown to be improved when keeping a memory of answered questions. The suggested module "remembers" all the previously asked questions, together with the answers that were generated in response, and uses this information to improve the performance of the CBR retriever. Our model works similarly, in that it tracks the history of cases used (or not) at any point of the argumentative discourse. Accumulated information at parts of a discussion episode, about the usage of a certain (old) case, is usually helpful for speculations.

The rest of the paper proceeds as follows: Section 2 describes the argumentation and viewpoint elements of the system and their object-oriented modeling. Section 3 deals with the representation of cases, while Section 4 illustrates the integration of all the above with an example. Section 5 concludes the paper discussing future work plans.

2 Viewpoint-Based Argumentation

Our framework integrates previous work on the modeling and implementation of a Group Decision and Negotiation Support System for Argumentation Based Reasoning on the Web [9], [10] with studies on the argumentative process in cooperative design [19] and viewpoint modeling [20]. The platform system is implemented in Java and can be run using any standard Web browser. It maps a multi-agent decision making process to a discussion graph with a tree-like structure. Throughout the paper, we refer to a real example about the planning of cyclepaths in the city of Bonn (Figure 1). The agents involved represent two parties: the Cyclists Union and the City Hall Planning department. The discussion is about the selection of a plan among two alternatives.

2.1 Argumentation Elements

The argumentation elements of our framework are issues, alternatives, positions, arguments, and preferences (due to space limitations, we focus here on the CBR-related elements and features of the Argumentation System; for a more comprehensive description, see [10]). *Issues* correspond to decisions to be made, or goals to be achieved (e.g., "planning of cyclepaths for the city of Bonn"). They consist of a set of alternatives that correspond to potential choices (e.g., alternatives a_1 : "construct a ring around the city center", a_2 : "select the already planned cyclepath *in Oxfordstrasse*"). *Positions* are asserted in order to advocate the selection of an alternative, or avert the agents' interest from it. For instance, position $p_{1.1}$: "it is faster to move around the city using the ring" is asserted to support a_1, while position $p_{1.3}$: "two car lanes will be replaced by a single one in some streets" to express one's objection to a_1. Positions may also refer to some other position in order to provide additional information about it (e.g., positions $p_{1.1.3}$: "no traffic congestion with pedestrians (when using the ring)", and $p_{2.1.1}$: "there is enough space already available in Parking Houses (providing details about $p_{2.1}$)"). *Arguments* are tuples of either the form $(position, link, position)$ or $(position, link, alternative)$, where a link marked by + denotes a *supporting argument* and a link marked by $-$ a *counterargument*. In other words, arguments link together a position with an alternative (e.g., $(p_{1.1},+,a_1)$ is a supporting argument for a_1) or another position (e.g., $(p_{2.1.1},\text{-},p_{2.1})$ is a counterargument for $p_{2.1}$). As in real life instances, two or more conflicting arguments can be simultaneously applied.

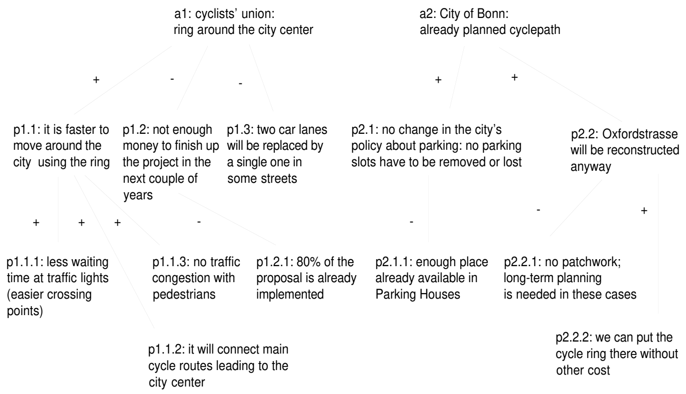

Fig. 1. An instance of the discussion.

Alternatives and positions may be *active* or *inactive*, depending on the related argumentation. The system involves numerous procedures for the propagation of the argumentation up in the discussion tree, such as *labelling* of the argumentation elements according to the different *proof standards* (they correspond to the type of evidence needed to decide if an element is active or not), aggregation of preferences, *consistency checking*, *scoring mechanisms* (in order to decide which is the best alternative), etc. The argumentation framework combines concepts from various well-established areas such as Decision Theory, Non-Monotonic Reasoning, Constraint Satisfaction and Cognitive Modeling. As a stand-alone module, it can act as an assistant and advisor, by recommending solutions and leaving the final enforcement of decisions and actions to the agents. It facilitates access to the current knowledge by making available all relevant data and documents (with URL links), and maintaining them in a well-structured way.

2.2 Viewpoint Elements

While the previous section focused on the argumentation elements *per se*, this one considers argumentation from the agents' perspective. Generally speaking, the *viewpoint* of an agent involved in a group decision making process consists of the (implicit or explicit) value system references which guide his action. The concept of viewpoint [20] is *agent-oriented*. It represents the general interests and - implicitly - goals of an agent, by maintaining lists of *predicates* and *inference schemata* adopted by him for the issue under discussion. In any case, an agent *represents* a viewpoint, while a viewpoint is *shared by* one or more agents. Except of an Id, viewpoint consists of the following parts:

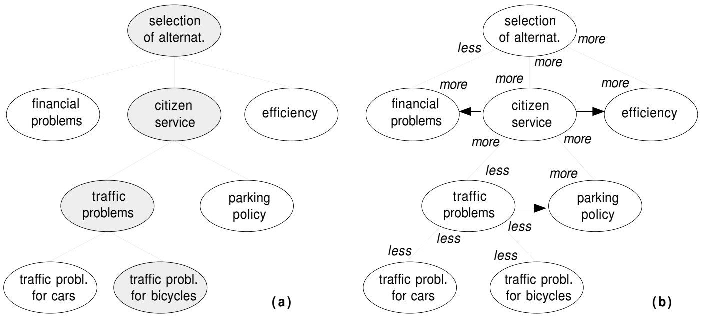

Fig. 2. Viewpoints involved in the discussion of Figure 1.

discussionContext: Describes the semantics of the discussion. More specifically:
- domain: The broader discussion domain (e.g., medicine, environment, etc.);
- type: The broader discussion type (e.g., group decision making, cooperative problem solving, etc.);
- dictionary: Consists of domain-dependent *topical fields* (i.e., predicates which have been previously used for the classification of cases and will be used in the future for retrieval purposes), organised in a hierarchical way, as illustrated in Figure 2a (shaded nodes denote topical fields that belong to both City Hall and Cyclists Union agent dictionaries). The notion of topical field relates to Aristotle's concept of *Topics* and corresponds to an (explicit or implicit) attribute. For instance, in the position *p1.1* the topical field can be *move-fast*.

inference schemata: They represent the various ways that agents relate topical fields with. Inference is the normative aspect of reasoning. Agents follow certain (logical) rules in order to defend their viewpoints or defeat those of their opponents. Such schemata can be (as positions and alternatives) *active* or *inactive*, depending on the argumentation underneath them. Moreover, an inference schema can be *consistent* or *inconsistent*, depending on the other schemata attached to the discussion. Our model includes the following two types of schemata (we don't claim that the list is exhaustive; however other schemata, suitable to a particular type of discussion, can be easily incorporated):

preferences: they provide a qualitative way to weigh reasons for and against the selection of a certain course of action by weighing the predicates of two different positions. Preferences are tuples of the form $(topical\_field_1, relation, topical\_field_2)$, where the *relation* can be ">", "=" or "<". $(topical\_field_1, >, topical\_field_2)$ is interpreted as $topical\_field_1$ is more important than $topical\_field_2$. Preferences may attach various levels of importance to positions or alternatives in the discussion graph (preferences are denoted with arrows in Figure 2b).

topical relations: Topical relations [19] are tuples of the form $(sign_1, topical\_field_1, sign_2, topical\_field_2)$, where *sign* can be one of more, less (Figure 2b). (more, $topical\_field_1$, less, $topical\_field_2$) is interpreted as "the more an object A has the property $topical\_field_1$, the less an object B has the property $topical\_field_2$" or "the more $topical\_field_1$, the less $topical\_field_2$" (for an extensive description of topical relations, see [19]).

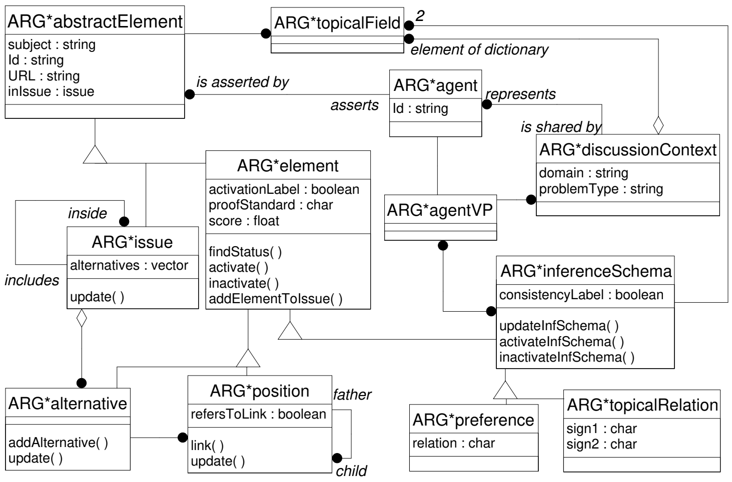

Fig. 3. OMT diagram of the argumentation and viewpoint elements.

2.3 O-O Model Representation

Following an object-oriented approach, we have integrated a part of the Viewpoint model suggested in [20] with the above model of argumentation, the aim being to have a viewpoint-based representation of cases in order to support argumentation in multi-agent settings.

Figure 3 illustrates the OMT diagram for the viewpoint and argumentation elements of our framework (Object Modeling Technique (OMT) [13] is one of the most well-tried analysis and design methods, able to illustrate object-oriented systems from three perspectives: *object diagrams* showing data structures and their relationships, *functional diagrams* showing data flow between processes, and *dynamic models* describing events, states and causal dependencies). Note that each abstractElement includes a list of *topicalFields* and a *url* corresponding to a http address where all the relevant documentation has been stored. Topical fields are currently denoted manually by the users; a semi-automatic field annotation is a future work direction. Furthermore, each element is now linked to a viewpoint through the agent that has asserted it. With such dependencies, we can retrieve the viewpoints that "speak" about a certain topical field by using the dictionary attached to each declared viewpoint.

3 Case Representation

The representation of a case should clearly reflect the purpose for which it will be used [5]. Aiming at providing the ability of extracting multiple views of cases representing the same data, we follow a hybrid approach based on the classical case representation [11] and the structure of the argumentation graph[1] (Figure 4). A case, in our framework, consists of a set of argumentation elements that directly depend on the current status of the discourse and the agents' viewpoints. Except of an Id, cases consist of the following parts:

situation: the relevant part of the discussion at the time the case has been stored; it is composed by:
- target: represents the argumentation element to be argued by an agent. It can be an issue, alternative or position (see different instances of the example described in the next section).
- discussion: the discussion which the case has been extracted from; it is related to *time* and includes: (i) initialIssue: the issue at the top of the discussion tree; (ii) discussionContext: information about the *domain* and the *problem type* the discussion refers to (e.g. cooperative planning); (iii) abstractElements (ordered list): refer to the corresponding discussion graph and describe the status of the dispute at the time the case has been involved. Cases have a link to the relevant part of the discussion tree they *refer to* (case situation). That is, whenever we store a case, we keep track of the related discussion graph (i.e., the issue it refers to, alternatives and constraints of the issue, agents in the discussion, discussion domain, etc.).

solution: it is the solution the system derives in order to argue about the target; the solution returned can be of the class *alternative* or *position*, depending on whether the case target above was an *issue* or *alternative*, respectively.

[1] The similarity of a case indexing tree structure and the argumentation graph of the model is rather straightforward.

evaluation: an indication of how well the case fits to the agents' agenda. It is calculated (using various formulas depending on the discussion domain and type) from the number of the current's case brotherCases (cases with the same target element) and childrenCases (cases that have as target the solution element of the current case).

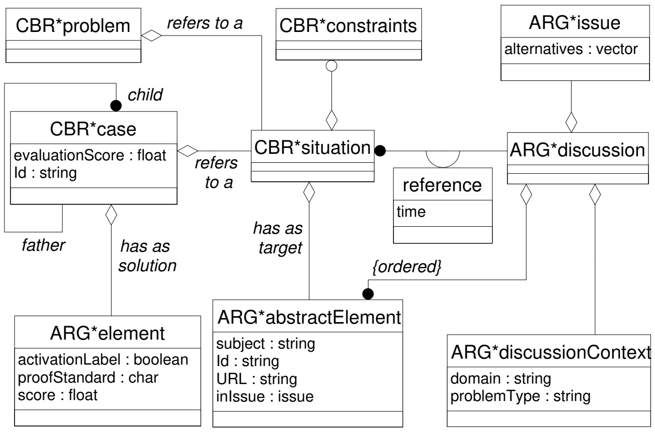

Fig. 4. OMT diagram for a case.

As shown in Figure 4, a problem is defined by a situation together with a constraints part, representing the conditions set by an agent. They may be different each time, depending on the agent's intensions, and are associated with *discussion* and *case filtering*. In addition, some of them (soft constraints) may be relaxed in order to retrieve more cases. They may include elements such as *caseType* (it can be *pro* or *con*, depending on whether the agent wants to advocate or express some objection for the target element, respectively), *problemType* of the discussion, and numerous other elements from the argumentation and viewpoint classes. For instance, the query "retrieve positions that speak against the selection of an alternative, and have been brought up by agents that don't represent public departments and hold inference schemata that incorporate the topical field(s) of the required positions" involves the following constraints: (i) `case.solution.link = "-"`, (ii) `agent.Discussion_Context` $\neq$ `"public_department"`, and (iii) $\exists$ `solution.topicalField in agent.inference.topicalFields`. Finally, *temporal constraints* describing various events in the argumentation graphs of the retrieved discussions can be also incorporated here.

4 CBR and Argumentation Based Reasoning

In the model proposed in this paper, control switches from CBR to argumentation-based reasoning and vice-versa, depending on the task to be performed. As mentioned, each agent "enters" a discussion by making clear his own viewpoint to the others. For the example of the paper, the *cyclist_ union agent* is aware that interests and preferences of the *City_ Hall agent* focus on financial aspects, while he makes clear that his own interests are on the quality of the citizen service. Argumentation with CBR includes four phases: (i) *intension submission*, (ii) *case retrieval and selection*, (iii) *case adaptation*, and (iv) *argument assertion*.

discussion_id: pl/routes/96-07 May 20, 1996

topIssue: planning of cyclepaths in the city of Bonn, *by City Hall, 96-04-15*
issue_id: pl/routes/96-07/i_1 *additional info*
alternative: ring around the city center, *by Cyclists Union, 96-04-17*
alt_id: pl/routes/96-07/a_1 *additional info*
position_pro: faster to move around using the ring, *by Cyclists Union, 96-04-30*
position_pro_id: pl/routes/96-07/p_1.1 *additional info*
warrant_cases: *pending* primary_key: citizen service
position_con: no money to finish up in the next couple of years, *by City Hall, 96-05-02*
position_con_id: pl/routes/96-07/p_1.2 *additional info*
warrant_cases: *pending* primary_key: financial aspects
position_con: two car lanes to be replaced by one, *by City Hall, 96-05-20*
position_pro_id: pl/routes/96-07/p_1.3 *additional info*
warrant_cases: *pending* primary_key: traffic aspects
alternative: already planned cyclepath, *by City Hall, 96-04-15*
alt_id: pl/routes/96-07/a_2 *additional info*
position_pro: no parking slots to be removed or lost, *by City Hall, 96-05-02*
position_pro_id: pl/routes/96-07/p_2.1 *additional info*
warrant_cases: *pending* primary_key: parking policy
position_pro: Oxfordstr. will be reconstructed anyway, *by City Hall, 96-05-07*
position_pro_id: pl/routes/96-07/p_2.2 *additional info*
warrant_cases: *pending* primary_key: efficiency

agents: *City Hall* *viewpoint* *additional info*
Cyclists Union *viewpoint* *additional info*

Fig. 5. CBR and Argumentation Based Reasoning: An early instance.

Agents first submit their intensions, by declaring the arguments they want to bring up in the discussion. This phase is considered to be a mapping of each agent's viewpoint to the current discussion. The explicit declaration of agents' intensions "drives" the argumentation process by motivating search for similar instances in the case base (search should be oriented towards similar argument structures). Agents' intensions implicitly specify the *CBR agenda*, i.e., actions to be performed through the case base (at the next phase). Figure 5 illustrates an early instance of the discussion (as of May 20, 1996), where the *City_ Hall agent* intends to argue against alternative a_1 using financial (position $p_{1.2}$) and traffic (position $p_{1.3}$) reasons, while he wants to support alternative a_2 for their advantages on parking policy and efficiency aspects (positions $p_{2.1}$ and $p_{2.2}$, respectively). Note that, at this point, the *cyclist_ union agent* only intends to support a_1 for citizen service reasons (position $p_{1.1}$); he has no desire to challenge a_2. An entry being at this phase is indicated by the slot `warrant_cases:`*pending* .

Case retrieval is performed with the use of topical fields from agents' dictionaries. The model initially checks the case base for precedent instances with the same field(s) at the target case element, taking into account the situation of the desired case as specified by the constraints (for the domains we address, when target is an alternative, the topical field used is *"selection of alternative"*). A simple case base query related to the intended position $p_{1.2}$ can be of the form: "give me all cases where the selection of an alternative is argued via financial aspects". We can further restrict the query, asking for cases where the selection of an alternative is objected due to financial reasons (as in the type of argument that the *City_ Hall agent* intends to assert using position $p_{1.2}$). However, with similar types of query relaxation, users may also retrieve *opposite cases*, possibly useful during the adaptation phase. During the case retrieval phase, agents may also alter their viewpoints, while observing similar precedent instances under the presence of certain participants in the corresponding discussions.

```
discussion_id:pl/routes/96-07                                          May 31, 1996

topIssue:planning of cyclepaths in the city of Bonn, by City Hall, 96-04-15
     issue_id: pl/routes/96-07/i_1     additional info
   alternative: ring around the city center, by Cyclists Union, 96-04-17
          alt_id: pl/routes/96-07/a_1  additional info
       position_pro: faster to move around using the ring, by Cyclists Union, 96-04-30
             position_pro_id: pl/routes/96-07/p_1.1     additional info
             warrant_cases: pl/sel_srv/07
          position_pro: less waiting time at traffic lights, by Cyclists Union, 96-05-05
                position_pro_id: pl/routes/96-07/p_1.1.1     additional info
                warrant_cases: nil
          position_pro: no congestion with pedestrians, by Cyclists Union, 96-05-10
                position_pro_id: pl/routes/96-07/p_1.1.3     additional info
                warrant_cases: pending     primary_key: pedestrians
       position_con: no money to finish up in the next couple of years,by City Hall, 96-05-02
             position_con_id: pl/routes/96-07/p_1.2     additional info
             warrant_cases: pl/sel_fin/18, ds/sel_fin/34
          position_con: 80% of the proposal is implemented, by Cyclists Union, 96-05-30
                position_pro_id: pl/routes/96-07/p_1.2.1     additional info
                warrant_cases: nil
       position_pro: funding is feasible-EEC directive, by Cyclists Union, 96-05-13
             position_pro_id: pl/routes/96-07/p_1.4     additional info
             warrant_cases: ds/sel_fin/34, ds/fin_fund/03
   alternative: already planned cyclepath, by City Hall, 96-04-15
          alt_id: pl/routes/96-07/a_2  additional info
       position_pro: funding is feasible-EEC directive, by City Hall, 96-05-02
             position_pro_id: pl/routes/96-07/p_2.1     additional info
             warrant_cases: nil
          position_con: enough place in Parking Houses, by Cyclists Union, 96-05-07
                position_pro_id: pl/routes/96-07/p_2.1.1     additional info
                warrant_cases: pending     primary_key: parking places

agents:    City Hall         viewpoint     additional info
           Cyclists Union    viewpoint     additional info
```

```
case_id:pl/sel_srv/07

situation:
     target:select_alternative
     discussion:
         initialIssue: highway construction
         discussionContext:design, cooperative
         abstractElements:list_ds_22
solution: the new highway provides easier access
            to a lot of communities
evaluation:
     brotherCases:pl/sel_eff/02, pl/sel_tr/19
     childrenCases:nil
```

```
case_id:ds/sel_fin/34

situation:
     target:select_alternative
     discussion:
         initialIssue: EEC funding acquisition
         discussionContext:planning
         abstractElements:list_pl_12
solution: national funding should cover at least
            half of the budget
evaluation:
     brotherCases:ds/sel_eff/07
     childrenCases:ds/fin_fund/03
```

Fig. 6. CBR and Argumentation Based Reasoning: A second instance.

Case selection and *case adaptation* are based on agent viewpoints and the current status of argumentation. Assume that two cases have been retrieved for the above query, one with caseType:pro and another with caseType:con. *City_ Hall agent* intends to bring up an argument against the selection of alternative a_1 due to financial aspects, so he may use the first case. Similarly, *cyclist_ union agent* may use the second one to challenge the argument of the *City_ Hall agent*. In any case, before the final argument assertion, *case adaptation* should be performed. While case selection is automatic, case adaptation is semi-automatic, in that the system proposes potential matches and the user selects the cases he thinks appropriate to adapt (according to the context of the current discussion) and use. Potential matches correspond to combinations of *caseType* with the *topical inferences* included in viewpoints. Shortly described here, *ranking* of best cases is performed according to the number of *brother* and *children cases* of the ones retrieved, the justification being that the more cases are related to them, the more robust they are (due to their potential challenge in previous disputes).

Using the retrieved (and possibly adapted) cases, agents provide warrants for their assertions. The *argument assertion* phase involves firing of the appropriate discourse acts for the propagation of the information in the discussion graph, and storage of the new case used. Figure 6 illustrates a later instance of the same discussion (as of May 31, 1996), where further argumentation has been provided. Samples of cases used at this instance appear at the lower two windows of the figure. Note that some of the initial intentions may have been completely discarded as the discussion evolves (see, for instance, the ones initiated by positions $p_{2.2}$ and $p_{1.3}$ in Figure 5), possibly due to unavailability of similar cases and/or the evolution of the viewpoints of the related agents. Also that case $ds/sel\_fin/34$ is used in both a position_pro and a position_con. This is due to different interpretation of the case by the two agents (*Cyclists_ Union agent* has also considered a childrenCase of $ds/sel\_fin/34$ - browsing $list\_pl\_12$ of abstractElements - that seems to better warrant his intended assertion). As shown in the last two figures, discussion is organized in a structured way, where entries (argumentation elements) are indexed according to their role and function. Among other relevant information, entries include references to the cases used as warrants and *primary_ keys* for the indexing of cases. Finally, references to the participating agents and their viewpoints are provided.

5 Concluding Remarks

Our main motivation for the framework suggested in this paper is to provide direct computer support for argumentation and negotiation with case-based reasoning, especially in weak domains. The argumentation part of the system is already implemented in Java, the aim being to deploy it on the web. What agents need to participate in a discussion is only a standard browser. Exploiting Web-based technology, our framework meets practical requirements such as relatively inexpensive access to a broad public, intuitive interfaces in order to be easily usable by inexperienced users, and availability on any prominent operating system and hardware platform. We focus on distributed, asynchronous collaboration, allowing agents to surpass the requirements of being in the same place and working at the same time.

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