The C-IPS Agent Architecture for Modeling Negotiating Social Agents

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Abstract. The basic concepts in agent negotiation are negotiation object, negotiation protocol and reasoning process. While aiming to transfer sociological concepts into multi-agent systems, where agents coordinate themselves by negotiation, we recognized the need for a more detailed structure. Therefore we developed C-IPS, which is presented in this article. It distinguishes between external constraints and internal reasoning processes. The reasoning process covers decisions regarding the negotiation issue, the partner, and a particular step. Its modularization supports the development of agents with different degrees of autonomy. The components of the C-IPS architecture are modeled according to the BDI approach. As an example for the application of C-IPS we consider agents that are required for the INKA project.

1 Introduction

Within the last years distributed artificial intelligence has been more and more influenced by social sciences. Sociological concepts have been considered as a promising way to describe and construct groups of agents and their interactions, to model and to simulate human societies, and to evaluate computer-human relations. However, in designing multi-agent systems (MAS) sociality is often considered in a very general way, where social refers to the ability and practice of interaction. In the social simulation domain sociality is more deeply addressed. For instance, the domain-independent *PECS* agent architecture incorporates social status as one of four important parts of the agent's reasoning process [18]. Contrary, we believe that social concepts cannot be localized within specific parts of the agent architecture, but they are a property of the complete architecture and its specific implementation.

The transfer of sociological concepts is a vital part of our *INKA* project, which is carried out in the context of the DFG priority program *Socionics*[1]. The project's aim is a system that enables experiments where artificial agents negotiate with humans. For that, we need agents that support different degrees of delegation within negotiations. Our application domain is shift exchanges in

[1] It supports research projects that combine sociology and computer science.

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a hospital, but we do not develop a new system for shift plan creation. For the transfer of sociological concepts we have to analyze which parts of the agents' architecture are influenced by which concepts and how do these parts interact. Such an analysis requires a well-structured reasoning process of the agent. Therefore, we propose the C-IPS structure. Combined with the Belief-Desire-Intention (BDI) approach, C-IPS provides a flexible architecture for negotiating agents. It supports a modular development as well as different degrees of agent's autonomy, i.e. different kinds of decisions can be delegated to the agent.

First, the article presents the basic ideas of C-IPS. Then, we enhance C-IPS by adding concepts from BDI architectures. Based on the INKA project the article finally presents an example for agents that follow the C-IPS architecture. The example also shows how C-IPS supports the modeling of sociological concepts within the agent architecture.

2 Structuring the Reasoning Process by Means of C-IPS

In the MAS literature on agent negotiations the negotiation object, the negotiation protocol, and the reasoning process are considered as the most important concepts [7]. This does not explicitly include partners nor does it provide a structure for the reasoning process. Consequentially, the design might focus on the selection of negotiation steps and might underestimate the impact of autonomous issue and partner selections. Increasingly, researchers become aware of other reasoning processes negotiating people are involved in, e.g. partner selection processes [8]. C-IPS aims to handle such extensions in a more comprehensive manner (see Figure 1). The starting point is the distinction between external constraints (C) and the agent's internal reasoning process. The reasoning process is divided into three sub processes: issue selection (I), partner selection (P), and step selection (S). The definition of the constraints heavily influences the design of the reasoning process. Their interdependency can be roughly described as follows: The more restrictive the external constraints are, the easier the reasoning process of the agent can be, but also the less flexible the agent is. In fact, an agent might be able to negotiate everything, but the agent's designer usually restricts this by defining the range of *negotiation objects*. From this set the agent selects issues for negotiations. The negotiation issue determines the space of possible deals[2]. Another constraint is the *negotiation protocol*, which limits the sequence of negotiation steps. However, one can also imagine that the protocol is not given and the agents reason about the meaning of messages. C-IPS additionally emphasizes external constraints related to the choice of the *negotiation partner*. Sometimes the designers assume that the partners for conflict resolution are given by the conflict. This is not always true, because sometimes other agents might be helpful to solve the conflict, but have to be identified before, or even the conflict itself is not sufficiently circumscribed.

Within the internal reasoning process an agent has to decide the issue of the intended negotiation, the negotiation partner, and particular negotiation steps.

[2] The identity of negotiation objects and issue is the most restrictive constraint.

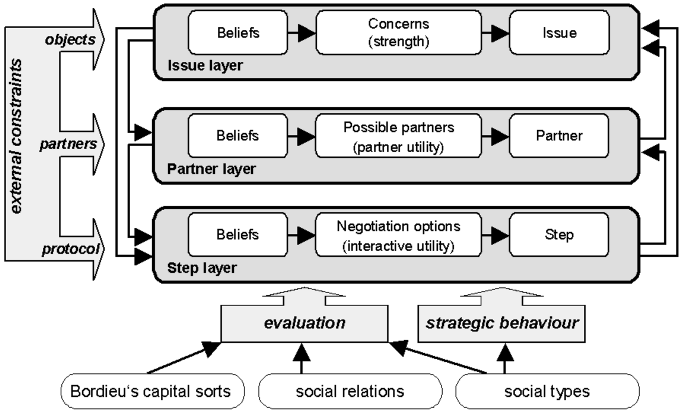

Fig. 1. The C-IPS-BDI architecture and the three sociological concepts we want to integrate into our negotiating agents.

Although these decisions are mutually dependent there is usually no common decision process. An agent architecture with three distinct components representing the three decisions enables and enforces the agents' designer to explicitly define the dependencies between them. For instance, an application may require that agents can change the issue during an ongoing negotiation or the set of partners might change. A structure anticipating the three distinct decisions can simplify the comparison of different negotiation architectures and agents' reasoning processes.

We propose that the structures of the three decision components follow the BDI approach [6,15]. B^k, D^k, I^k, with $k \in \{I, P, S\}$ denote the beliefs, desires, and intentions of the different components. $I = (I^I, I^P, I^S)$ refers to the global intention of the agent, which is interpreted as to do the step I^S in a negotiation on issue I^I towards the partner(s) I^P.

The beliefs B^k of each component contain knowledge about (1) states that might be reached and states that are temporarily recognized to be impossible to reach, (2) intentions chosen in other components, where applicable (3) the history of a ongoing negotiation, and (4) beliefs that are needed for specific implementations of the components. The beliefs are updated based on new perceptions P_t. The states an agent thinks about can either be explicitly given as beliefs or can be a result of a reasoning process based on the beliefs. The constraints limit the space of states. During the evaluation process the agent derives desires D^k, which represent the states it would like to reach. The preference function of each component gives degrees of desires, thus it discriminates between desires. Based on the preferences, the desires, the beliefs, the old intentions, and the knowledge about states that are recognized to be impossible (Imp^k) a component determines its new intention. When all parts of the global intention I have been chosen, the intention is put into action. Similar to [3] we can define:

$$B^k_{t+1} := update(B^k_t, P_t)$$
$$D^k_{t+1} := evaluate(B^k_{t+1}, D^k_t)$$

$$I^k_{t+1} := \mathit{filter}(B^k_{t+1}, D^k_{t+1}, I^k_t, \mathit{prefer}^k, \mathit{Imp}^k_t), \text{ with } \mathit{prefer}^k : D^k_{t+1} \mapsto \mathbb{R}$$
$$\mathit{Action}_{t+1} := \left\{ \begin{array}{ll} \mathit{act}(I_{t+1}) & \mathit{if}\ I^I_{t+1} \neq \emptyset \wedge I^P_{t+1} \neq \emptyset \wedge I^S_{t+1} \neq \emptyset \\ \emptyset & \mathit{otherwise} \end{array} \right\}$$

If the evaluation cannot find desires or the filter function cannot select an intention, then the agent recognizes that the currently chosen intentions of the other components represent (at least temporarily) states that are impossible to reach[3]. These states are members of the set Imp^k_t. To indicate how long they are assumed to be impossible, the agents assign durations to them. After a negotiation or an unsuccessful request for a negotiation an agent sets the partner for the issue as temporarily impossible[4].

Strategic behavior is a concept often used to describe human negotiations, which goes beyond pure short-term optimization. Defining strategic behavior as a behavior such that agents deviate from the individually most preferable choice to reach better results [4,10], we can locate strategic behavior within the process that selects intentions from desires. Hence, we assume that strategy is not about what is good for an agent, but it is procedural knowledge about useful behavior given some preferences. Strategies are not restricted to one step but have a mid or long term perspective. This knowledge can be acquired in the long run or is implemented by the agent's designer (as it is done in the INKA project). We distinguish isolated strategic behavior from coalitions. Currently we only consider isolated strategic behavior, where agents do not mutually coordinate their deviations from personal preferences.

3 Applying C-IPS in the INKA Project

In this section we describe how C-IPS is applied in the INKA project, where artificial agents and humans negotiate the exchange of shifts in a hospital domain [13]. Let S be the set of all shifts and A be the set of agents. Agents initiate negotiations to solve conflicts between the shift plan and their individual leisure time interests.[5] Let $SP_t \subseteq S \times A$ be the shift plan at time t, which relates shifts to agents and $SP_t(a) = \{s \mid (a, s) \in SP_t\}$ the personal shift plan of an agent a. The function $lt_t : S \mapsto \mathbb{R}$ assigns each shift a value between zero and one, where zero means no interest and one represents the strongest interest to have free. The initiator's goal is to exchange a conflict-raising shift.

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[3] For instance, if the current global intention I is $(I^I_1, \emptyset, \emptyset)$, i.e. partner and step have not been not chosen yet, and the partner component cannot select a partner, then $(I^I_1, \emptyset, \emptyset) \in Imp^I$.

[4] Thereby we avoid deadlocks when agents initiate negotiations again and again and possibly block other agents.

[5] Although very interesting for human-like negotiations, we currently exclude the concept of argumentation in negotiations, i.e. agents do not explain why they did particular decisions or what preferences they have (e.g. [14,17]).

3.1 Social Concepts to Be Integrated

The INKA project requires the integration of Bourdieu's capital sort theory as a way to evaluate behavioral alternatives. Furthermore, it requires agents to reason about social types and to build and maintain relations to other agents. As the theoretical background of these concepts is not emphasized in this paper we give only a brief overview.

Bourdieu's capital sorts. When people negotiate they may pursue different goals. Before and during a negotiation they have to evaluate different possible agreements, e.g. shift exchanges. These options usually have many properties that may contribute in several ways to the fulfillment of different goals. Such evaluation processes are subject to research in multi-criteria decision-making and multi-attribute utility theory (MAUT). Both provide mechanisms to model and to solve such problems (e.g. [12]). To apply these mechanisms in the agent design process, the agent's designer has to select the most relevant properties and goals. This task can sometimes be very difficult, especially if there are many of them or if they are not easily to identify. This is the case in our application. In sociological theory aggregation and generalization is used to reduce the complexity of the description of humans, their goals, and the properties of opportunities to fulfill them. Similar to [16] we apply Bourdieus' capital sort theory to reduce the complexity of many goals and complex properties. In order to describe the human behavior we assume that a person or an agent would like to accumulate capital. Doing this he has preferences for different capital sorts, while different alternatives of the behavior have different contributions to these capital sorts [1]. The INKA project considers economic, social, cultural, and symbolic capital [13]. The contributions of different shift types, i.e. early, late, and night shifts during working days and at the weekend, were calculated according to [11].

The utility function $U : \mathbb{R}^4_{[0,1]} \times \mathbb{R}^4 \mapsto \mathbb{R}$ maps the capital interests (ci), given as values, which are between zero and one and sum up to one, and a capital equipment (ca) to a real value. This function incorporates concepts of MAUT. Until a refinement by experimental evaluations we calculate $U(ci, ca)$ as the weighted sum $\sum_{i=1}^{4} ca_i \cdot ci_i$. An agent's capital equipment is defined by its personal shift plan. The capital assigned to a shift is given by $ca_S : S \mapsto \mathbb{R}^4$. The value sv of a shift s is defined as the difference between the value of the agent's capital equipment with and without the shift. Because of the additivity of U this can be simplified to $sv(ci, s) = U\left(ci, cp_S\left(s'\right)\right)$. Similarly, the value of an exchange is defined, with s being the shift to give away and s' the shift to take in return: $ev(ci, s, s') = U\left(ci, cp_S\left(s'\right) - cp_S\left(s\right)\right)$.

Social types. An important sociological concept within the INKA project is the social type. Let the set T contain all social types then the function $st : A \mapsto T$ assigns each agent a social type. For each social type we assume typical values of agent attributes. The attributes of social types can be divided in attributes that guide the evaluation processes and attributes that are related to the actual behavior of an agent. The capital interests ($ci_T : T \mapsto \mathbb{R}^4_{[0,1]}$), the general interest to work ($ww_T : T \mapsto \mathbb{R}_{[0,1]}$), the willingness to negotiate ($wn_T : T \mapsto \mathbb{R}_{[0,1]}$), willingness to compromise ($wc_T : T \mapsto \mathbb{R}_{[0,1]}$), the importance of personal and typified relations ($ipr_T, itr_T : T \mapsto \mathbb{R}_{[0,1]}$), and the typified leisure time interests ($lt_T : T \times S \mapsto \mathbb{R}_{[0,1]}$) belong to the first group. The willingness to give information ($wi_T : T \mapsto \mathbb{R}_{[0,1]}$) directly influences the behavior, hence it belongs to the second group.

The self-perception of an agent, i.e. the class it assigns to itself, is a frame that guides the agent's individual behavior. The only attribute that is not strictly applied within the self-perception is the typified leisure time interest. An agent can have leisure time interests that differ from the ones give by the social type. The social type that is assigned to another agent is used to estimate the other agent's behavior. Such classifications enable people in social contexts, as well as agents in MAS to reduce the complexity of their decision-making process and – much more interesting – it adds a generalization mechanism. In fact, experiences with one agent out of a class might be attributed to all agents in this class. A more detailed introduction to the idea of multi-dimensional social types within MAS can be found in [13].

Social relations and altruism. In human interactions one can frequently observe the formation of relation networks. On the one hand, such relations affect the tendency to negotiate with particular persons. On the other hand people are often more willing to make concessions towards others they have a good relationship with. These concessions can be interpreted as taking the other agents' preferences into account, i.e. behave more altruistically. In our model an agent i assigns a value to each agent $r_t : A \mapsto \mathbb{R}_{[0,1]}$, where, zero (one) denotes a bad (good) relation. Since the relations can change dynamically, and the focus of our modeling is the negotiation itself, we consider the formation of relationships depending on the agents' experiences in past negotiations. Relations improve and get worse on the basis of successful or unsuccessful negotiations. Other examples for experience-based partner selection mechanisms can be found in [5,17].

Consequently applying the concept of reasoning about social types, we introduce typified relations, which represent relations to social types. This implies that agents also maintain values for each social type, i.e. $r_t : A \cup T \mapsto \mathbb{R}_{[0,1]}$. Thereby, we generalize experiences with individual agents to social types, i.e. experiences to single agents are also attributed to its social type. This implies that the typified relation to an agent can contradict the personal relation to it.[6]

Using the C-IPS we can make our interpretation of the two mentioned effects of social relations, preferring particular partners and behaving altruistically, more explicit. The issue component does not depend on social relations. In the partner component partners are chosen, which an agent has good relations with. In both, the issue and partner component, no altruistic behavior is applied. In fact, agents do not explicitly prefer other agents as partners, just because they

[6] For instance, an agent might prefer to negotiate with agents of the social type workaholic but does not like to do it with agent Bob, who is a workaholic.

would benefit from a negotiation. In the step component the agents behave altruistically towards agents they have a good relation with. Contrary to our *passive altruists*, active altruist would behave altruistically in the other components, too.

3.2 The INKA Agents

After briefly introducing the sociological concepts we apply, we now present the details of the INKA agents' reasoning processes. Doing this we follow the structure given by the C-IPS architecture. In the reasoning process we focus on the desire and intention selection.

External constraints. Within the hospital there are formal guidelines, e.g. prohibitions to possess certain configurations of shifts or to exchange shifts between people with different hierarchical positions or qualifications. Although these limitations are implemented in the agents there is an administrative instance that has to confirm every exchange. This is especially important for cases when incomplete information exist.[7] The function $allowed : A \times S \times A \times S \mapsto \{true, false\}$ gives for an exchange[8] whether it is formally allowed or not.

The negotiation objects are all formally allowed shift exchanges between two agents. As designer's restrictions we additionally assume that the issue is limited to a single shift that the initiator of a negotiation wants to give away. The negotiation is then on the shift the initiator has to take in turn from the other agent (responder)[9]. We also require that both agents, a and a', have to possess the shift they give away and have to be able to take the shift offered in return:

- $I_t^I = \{(a, s, a', s') \mid (a, s, a', s') \in S \times A \times S \times A \wedge allowed(a, s, a', s')\}$
- $\forall (s, a, s', a') \in I^I : s \in SP_t(a) \wedge s' \in SP_t(a') \wedge s' \notin SP_t(a) \wedge s \notin SP_t(a')$
- $\forall (s_1, a_1, s_1', a_1'), (s_2, a_2, s_2', a_2') \in I^I : s_1 = s_2'$

For the partner component we require that the negotiation partner should be able to contribute to the issue of the negotiation, thus

$$I_t^P \in A \text{ and } \exists (a', s', a'', s'') \in I_t^I : I_t^P = a''$$

A negotiation step consists of a performative and where appropriate of an exchange. The negotiation protocol usually restricts the sequence of performatives, while the negotiation issue restricts the exchange. Informally negotiating people rarely use the contract net protocol; they instead show very flexible negotiation courses. We allow agents to do proposals, to agree on a proposal, and to cancel the negotiation. Additionally, the agents can make an ultimatum, which means that the negotiation is canceled in the next step if the other agent does not agree. A call-for-proposal (cfp) enables agents to ask for another proposal.

[7] The agents may be not able to recognize that an exchange is prohibited.

[8] An exchange describes the two agents and their originally assigned shifts.

[9] Further work will be concerned with relaxing these restriction in order to enable more complex exchange-operations like cyclic-exchange.

Agreeing can follow only a proposal or an ultimatum; hence the cfp prevents the other agent from agreeing. Before the exchange of proposals the initiating agent requests the partner for a negotiation. Since our agents cannot yet negotiate with several agents in parallel, the request implies the question whether the other agent is busy or not. It also contains the question whether there have been changes in the other agent's shift plan or interests since the last negotiation on the same issue. Thereby agents can avoid redundant negotiations that may result in negative experiences. After the negotiation, a possible reached agreement has to be confirmed by the administration. The initiator requests this and forwards the answer to the responder.

Layer dependencies. Although the C-IPS architecture allows the definition of complex dependencies between the components, during the first application we follow a simple sequential model. After calculating the issue, the partner is selected. The issue and the partner guide the step layer. From this we get the following conditions $I_t^S \neq \emptyset \to I_t^P \neq \emptyset$, $I_t^P \neq \emptyset \to I_t^I \neq \emptyset$, $I_t^I = \emptyset \to I_t^P = \emptyset$, and $I_t^P = \emptyset \to I_t^S = \emptyset$. If an agent becomes a responder the received negotiation request determines its issue and its partner.

Issue layer. A need for negotiation always arises when there is a sufficiently strong conflict between the administratively given shift plan and the individual leisure time interests. Variable leisure time interests, which can not really be forecasted by the administration, result from events outside the hospital. They are therefore an aggregate of the agent's goals outside the hospital. Agents not only balance between goals within and outside the hospital, but they also consider the fulfillment of different goals within the hospital. Bourdieu's capital sorts model the second aspect.

The beliefs of the issue component of agent a are its personal shift plan $SP_t(a)$, the own social type $st(a)$, and the leisure time interest $lt_t(s)$. Let $E_{a,s}$ be the set of all exchanges according to the external constraints, where an agent a can give the shift s away. The agent's concerns, i.e. desires of the issue component, are all $E_{a,s}$ such that for shift s there is positive leisure time interest. The strength, i.e. the preference to give a shift away, is determined by weighting the value of the shift and the leisure time interest at the time of the shift. This balancing is influenced by the agent's willingness to work. Let the utility functions su and eu represent this balancing process for shifts and exchanges with capital interests ci, shifts s and s' and leisure time interest l and l', then $su(ci, s, l) = ww_T(st(a)) \cdot sv(ci, s) + (1 - ww_T(st(a))) \cdot l$ and $eu(ci, s, l, s', l') = ww_T(st(a)) \cdot (sv(ci, s') - sv(ci, s)) + (1 - ww_T(st(a))) \cdot (l' - l)$. In the issue component we model only a very simple strategic behavior. We assume that for a negotiation there has to be a minimum leisure time interest, which is given by willingness to negotiate wn_T. Then the strongest concern related to a shift s with an $lt_t(s)$ above this threshold and being not recognized to be impossible is chosen as the intention of the issue layer.

$$evaluate^I(B^I_{t+1}, D^I_t) = \{E_{a,s} \mid lt_t(s) > 0\}$$
$$prefer^I(E_{a,s} \in D^I_{t+1}) = 1/su(ci(st(a)), s, lt_{t+1}(s))$$

$$filter^I(B^I_{t+1}, D^I_{t+1}, I^I_t, prefer^I) = \underset{\{E_{a,s} | E_{a,s} \in D^I_{t+1} \wedge lt_t(s) > wn_T(a) \wedge (E_{a,s}, \emptyset, \emptyset) \notin Imp\}}{argmax} prefer^I(E_{a,s})$$

Regarding the sociological concepts, in the issue component the agents only use the concept of social types as self-perception. They reason based on Bourdieu's capital sorts, but they do not consider any kind of relations nor do they reason about other agents.

Partner layer. In the partner component, desires are partners that are possible according to the external constraints for negotiations on the given issue, i.e. $possible_t(a', s) = true$. The agents are ranked by a partner utility that depends on the personal and the typified relations as well as on a shift plan value $spv(a', E_{a,s})$ that is a measure for the quality and quantity of exchanges that are possible with another agent according to the given issue $E_{a,s}$. Within the preference function ipr_T and itr_T determine the impact of personal and typified relations. Varying this we can check whether considering generalized experiences can increase the overall performance or not.

$$evaluate^P(B^P_{t+1}, D^P_t) = \left\{ a' \mid a' \in A \wedge possible(a', I^I) \right\}$$

$$prefer^I(a' \in D^P_{t+1}) = r_t(a')^{ipr_T(st(a))} \cdot r_t(st(a'))^{itr_T(st(a))} \cdot spv(a', I^I_{t+1})$$

$$filter^I(B^I_{t+1}, D^I_{t+1}, I^I_t, prefer^I) = \underset{\{a' | a' \in D^P_{t+1} \wedge (I^I_{t+1}, a', \emptyset) \notin Imp^P\}}{argmax} prefer^I(a')$$

In the partner component we have included personal and typified relations. The agent develops experience-based preferences for selecting particular partners. Altruistic considerations are not modeled. After selecting an issue and a partner, the agent can initiate a negotiation.

Step layer. As described in the subsection on external constraints, the agents start a negotiation by requesting a negotiation. Contrary to desires at the other components, the desires in the step component do not concern a particular step. Instead desires are about desirable exchanges. All considered exchanges (exchanges covered by the issue and related to the partner) are ranked by the interactive utility. The interactive utility of an exchange $ie(a, a', s, s')$ incorporates our concept of altruism and is therefore calculated from the own utility of an exchange and from an social type based estimation of the other agent's utility of the exchange. Similar to [2] we calculate a weighted sum of both utilities: $ie\,(a, a', s, s') = (1 - \alpha_{a'}) \cdot eu\,(ci(st(a)), s, lt_t(s), s', lt_t(s')) + \alpha(a') \cdot eu\,(ci(st(a')), s, lt_T(st(a'), s), s', lt_T(st(a'), s'))$. The altruism factor depends on the relations and on a social type specific predisposition to behave altruistically (implemented by willingness to compromise): $\alpha_{a'} = r_t(a')^{ipr_T(st(a))} \cdot r_t(st(a'))^{itr_T(st(a))} \cdot wc_T(st(a))$. Altruism is often regarded as a way to overcome prisoner's dilemma-like situations. But if both agent are excessively altruistic (i.e. $\alpha > 0.5$), then they can experience such situations, too (see also [9]). By relating the cancel decision to the personal utility and the accept decision to the interactive utility we avoid these situations.

For the case a negotiation request is accepted, we assume that the negotiation takes place within a virtual zone: Exchanges are compared with two strategic lines, the accept line and the cancel line. If the other agent's proposal is good enough, i.e. its evaluation is above the accept line and above the cancel line, then it is accepted. If the proposal is too bad, i.e. below the cancel line, then the negotiation is canceled. Over time the accept line descends while the cancel line ascends. Hence the zone where agents further negotiate gets smaller and an end of the negotiation becomes more likely. If the proposal is above the cancel but below the accept line, then the agent does not wish to agree or to cancel, but does another proposal or cfp. The agent itself only proposes exchanges, which it would accept. These are the agent's desires.

From the desires and the knowledge about the protocol the agent derives a particular negotiation step as intention. A step is an appropriate performative according to the protocol (i.e. proposal, agree, cancel, cfp, or ultimatum) and additionally - if necessary - an exchange. Contrary to the issue and the partner component, we have modeled a complex strategic behavior in the filter process of the step component.

$$
\begin{aligned}
\mathit{evaluate}^S(B^S_{t+1}, D^S_t) = \{&(a, s, a', s') \mid (a, s, a', s') \in I^I_{t+1} \wedge a' = I^P_{t+1} \wedge \\
&\mathit{ie}(a, s, a', s') > \mathit{acceptLine}(t+1) \wedge \\
&\mathit{eu}(\mathit{ci}_T(\mathit{st}(a)), s, \mathit{lt}_t(s), s', \mathit{lt}_t(s')) > \mathit{cancelLine}(t+1)\} \\
\mathit{prefer}^S((a, s, a', s') \in D^S_{t+1}) &= \mathit{ie}(a, s, a', s') \\
\mathit{filter}^S(B^S_{t+1}, D^S_{t+1}, I^S_t, \mathit{prefer}^S) &= \\
&\mathit{strategy}(B^S_{t+1}, D^S_{t+1}, I^S_t, \mathit{prefer}^S, \text{set of weighted tactics})
\end{aligned}
$$

The basic concept of our implementation of strategy is a tactic. Tactics contain a precondition, usually referring to past negotiation steps and to both strategic lines, and a body that determines a particular negotiation step. The body can also be influenced by the history of the current negotiation.

While a tactic gives one negotiation step for a specific set of situations, a strategy provides a sequence of steps for a wide range of situations. We create a strategy from a set of tactics and the two strategic lines. To each tactic a weight can be assigned. If the preconditions of more than one tactic hold, the weights are taken into account. If necessary, the weights are temporarily adjusted. Applicable tactics without a weight are only considered if the sum of weights of all applicable tactics is less than 1. In this case the difference to 1 is equally distributed among the applicable tactics. If the sum is greater than or equal to 1, the tactics without a weight are not considered and the weights are normalized such that the sum equals 1. Using these weights as probabilities one tactic is chosen randomly. This flexible model of strategies as a set of partially weighted tactics enables us to merge, extend, or reduce strategies dynamically[10].

In our application we currently define four tactics: Agreeing and Canceling, which compare interactive and personal utilities of the partner's last proposal or ultimatum with the accept line and cancel line. The tactic Step-by-step is

[10] Although currently the strategy is fixed we plan to introduce adaptable strategies and learning mechanisms.

a simple heuristic to do a proposal. The agent proposes one negotiation option after the other starting with the one that is ranked highest. If there is no other option the last one is repeated and after 5 repetitions an ultimatum is done. This tactic is only applicable if Agreeing and Canceling are not applicable. The same holds for the fourth tactic, Cfp. These tactics are combined into a strategy. We assign a weight to the tactic Cfp that depends on the social type. It is inversely related to the willingness to give information. The accept line has an initial value that is five percent below the best-ranked negotiation option. It decreases 5 percent of the interactive utility of the best negotiation option each step. The cancel line starts at zero and increases half the absolute value the accept line decreases.

4 Conclusions

In this article we have proposed the C-IPS framework to model negotiating agents. The frequently used concepts of negotiation protocol, object, and reasoning process can be put into a broader context of external constraints and reasoning process. Both can be structured more detailed regarding the negotiation issue, the partner, and a particular negotiation step. This enforces a clear definition of concepts and ideas during the agent design. The three components of the agent's reasoning process we have modeled according to the BDI approach.

Although not being exhaustively, we give a deeper insight into the design of the INKA agents, thereby showing how the C-IPS architecture can be applied and how it can support the analysis and modeling of concepts like social types, social relations, and altruism. C-IPS has made visible that altruism in negotiations can be defined in different ways, e.g. passive and active altruists.

The component-based approach enables different degrees of delegation. By leaving different decisions to humans, we can implement four degrees. First, the human does all decisions; hence the agent is without any intelligence and is, in fact, only an interface. Second, the agent gets the issue and the partner, but negotiates on its own. Third, the agent gets only the issue of the negotiation. And forth, the agent even recognizes the concerns of the user and after several negotiations it just provides a better shift plan.

During the next steps we model more complex negotiations within the C-IPS approach, i.e. relaxing the sequential order of the components' decisions and enabling multilateral negotiations. Further we aim to improve the domain-independent formalization of C-IPS.

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