Introducing the IPS framework to model altruistic relation-building agents in negotiations

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Abstract. This paper presents INKA-agents negotiating on work shifts in a hospital. The agents develop altruistic relations to individual agents as well as to classes of agents. For modeling the agents' reasoning processes we introduce the three-layered IPS framework. Based on the BDI approach the framework assigns each part of the commitment that has to be done within negotiations (i.e. issue, partner, and step) a separate BDI layer. For selecting a partner and specific negotiation steps we develop a concept of passive altruism and combine it with personal and typified relations. Although applied to a specific domain, this architecture and the concept of altruism can be generalized to be useful in other negotiation contexts, too.

1 Introduction

Negotiation is a frequently used and studied mechanism for coordination within groups of agents. Many articles have been written about properties of best strategies and protocols for negotiations. Although the process of negotiation partner selection is a prerequisite for negotiations it has not gained much attention. This tendency becomes explicitly in [1, 8]. The authors label the most important concepts in agent negotiation research: (1) the negotiation object the agents negotiate on, (2) the negotiation protocol, which defines possible sequences of messages (negotiation steps) exchanged by the agents, and (3) the agent's reasoning process.

The reasoning process of agents is often structured according to the Belief–Desire–Intention (BDI) paradigm. Architectures built on this approach focus on how the beliefs, desires, and intentions of the agents are represented, updated, and processed to determine the agents' actions [5, 14]. Beliefs model what an agent knows about the world, desires model those states of the world that are preferable for the agent, and intentions are those states that the agent actively tries to bring about. According to [5, 17] BDI architectures can also be layered to deal better with highly complex applications. For negotiating agents the BDI architecture is not well established.

In the field of negotiation modeling, designers of multi-agent systems (MAS) have experienced that pure selfishness as the behavioral guide line can lead to sub-optimal results, e.g. due to situations like the prisoner's dilemma. Based on sociological insights, altruism as a way to overcome such dilemmas has attracted attention by several authors (e.g. [3, 7, 16]).

The transfer of sociological concepts to the design of MAS is one important goal of our INKA project[1] that is part of the *Socionics* research program[2]. The INKA project develops a role-based MAS for negotiations on the exchange of shifts within hospitals. Based on sociological fieldwork we recognized that individuals often apply concepts like social types instead of reasoning about other individuals as single entities only. We also observed that individuals build relations, which means their behavior depends not only on the current context and the properties the participating agents have but also on past experiences between both partners. As we aim to model lifelike negotiations we were not able to use simple protocols (e.g. like the contract net protocol), instead we had to define a more flexible one.

Negotiations of *INKA-agents*, like negotiations in general, require commitments concerning (1) a negotiation issue, (2) a negotiation partner, and (3) a single step of the negotiation. This is the starting point of our IPS framework that makes the dependencies between these three parts explicit. The three components are represented as interdependent layers, each structured by BDI approach. For the layers we describe how altruism is modeled and how the agents distinguish between different partners or classes of partners. Based on sociological research and empirical fieldwork the model is the base for a MAS that will be tested within a hybrid context. In fact, human actors and artificial agents will interact within our system. Hence, we go beyond social simulation, but combine it with laboratory experiments [12]. This enables us to experimentally evaluate the robustness of the system against different mixtures of human and artificial players and to test the social appropriateness of the behavior of artificial agents in the system.

After relating this article to our and other's previous work we introduce the layered IPS negotiation framework. Then we demonstrate how this framework can be filled with our relation- and altruism-based negotiation concepts. Subsequently, we report our experiences with this framework and show how it supports our research.

2 Related work

This article is based on two major concepts: architecture of negotiating agents and altruism to enhance group cooperation.

Contrary to the issue and partner selection, the step selection process has been widely discussed in literature on agent negotiations. However, agents may not only negotiate on given objects with given partners, but also actively initiate a negotiation. Hence, the question of how to select an issue and how to select

[1] *INKA* stands for Integration of Cooperative Agents in complex organizations.
[2] The Socionics program by the German Research Foundation DFG supports projects that combine scientific research in both sociology and computer science.

a partner requires more attention. Recently, [9] have modeled a pre-selection procedure that selects the partner according to a partner scoring function. [4] have presented an agent architecture that uses experiences with other agents as a guide for negotiation partner selection. That means, agents are not only social by the fact of interaction [17], but they build social relations by discriminating agents based on past experiences with them. This makes agent architecture a very complex issue. Layered architectures have been used to deal with the increasing complexity of agents (e.g. [13]).

Altruism can be defined and interpreted in different ways, but all are based on the assumption of donating something to increase the benefit of somebody else. [7] offers a classification of altruism according to three dimensions: (1) utility donated by the altruistic agent, (2) benefit received by the recipient of the altruistic act, and (3) the benefit the donor may recover in the future. This allows a distinction of several concepts of altruism, but in this article we follow a simple interpretation of altruism that is common in economics and agent theory (e.g. [16]): altruism as a normalized weighted sum of the own utility and an estimation of the partner's utility. This is a specific instance of the definition of altruism done by [2]. Similar to [3] we defined *personal utility* as the self interest and *interactive utility* as the weighted sum representing altruism. In this conceptualization altruism does not prevent dilemmas nor does it guarantee an increase in cooperation. Especially the existence of excess altruism, i.e. weighting the partner's utility higher than the own one, can cause prisoner's dilemma-like situations [10]. Designing an agent reasoning process that enables excess altruism, e.g. as an investment in relations, one should keep such dilemmas in mind. Often altruism is independent on the partner (e.g. [2, 7, 16]), but for relation-building agents a more subtle approach might be useful, hence making the altruism dependent on relations an agent has.

If the reasoning process takes relations to other agents into account the process might be very expensive in time and uncertain because of a lack of knowledge about a particular agent. In human societies individuals frequently apply concepts such as social types to reduce this effort. Even if it is not possible to recognize specific properties of an individual agent, it might be possible to put it into a class, i.e. to assign a social type. Following this idea [11] integrates the concept of social types into an MAS.

Our shift plan negotiations can be seen as a scheduling problem. Another MAS solving the scheduling problem by negotiations can be found in [15] but its focus is on preference revision mechanisms. Our own work does not focus on the scheduling problem itself but on the concept of altruistic relation-building agents that negotiate on some complex issues.

The utility an agent assigns to a work shift is based on the shift's contribution to four capital sorts according to a capital theory from sociology as it is described in [11]. During an agent's negotiation, which is initiated because the agent or its partner feels uncomfortable with a shift, agents fulfill a formal and a practical role. The first one describes formal, often explicitly given, restrictions to the behavior of agents, e.g. spatial arrangements, position in hierarchy, and the agent's functional area (see [6]). The latter one is a guide for the behavior in situations not completely covered by the formal role. The practical role is described by social types that imply a classification of agents (see [11]). As social types define behavioral assumptions and characteristic preferences, agents can reason about other agents, as well as about classes of agents, i.e. social types.

3 The IPS Framework

Having an interdisciplinary team of computer scientists and sociologists we need an intuitive way to structure negotiations that is detailed enough but not too technical. This is provided by the IPS framework as presented in Figure 1. The framework anticipates that the commitment, which has to be done for a negotiation, is related to three distinguishable concepts: the issue, the partner, and the specific negotiation step. Each can be done and withdrawn independently. The framework is open for modeling interdependent negotiations, like several negotiation partners for the same issue or several issues with one or more partners.

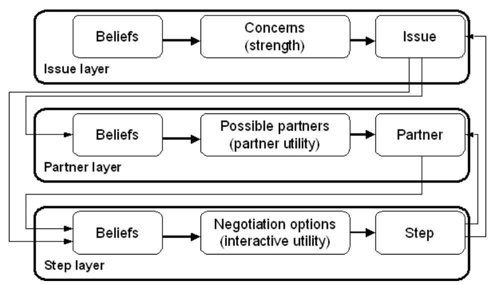

Fig. 1. IPS framework.

At the issue layer the agent has beliefs about the negotiation objects it might negotiate on. It derives desires, here referred to as concerns. They are ranked. The strength expresses the expected benefit a negotiation on that issue leads to. The strongest concern that is not recognized to be impossible (e.g. can not find a partner to negotiate on a specific shift) is chosen as intention at this layer. The second layer, i.e. the partner layer, derives the negotiation partner. Possible partners are ranked by a partner utility and the best one that is not an impossible partner, e.g. a partner already talked with, is chosen as the negotiation partner. At the step layer possible exchanges that are part of negotiation steps are ranked via the interactive and personal utility. By applying strategies and tactics the agent selects a specific negotiation step, which implies the selection of a performative (e.g. proposal, ultimatum, agree, cancel or call for proposal) and/or an exchange from the ranked set of possible exchanges.

In this model different interdependencies between the layers, especially in the policy on how to choose intentions at these layers, can be defined. As a first evaluation we have considered a simple straightforward policy, such that the commitments are done step by step starting at the issue layer and the withdrawals are done also step by step but starting at the step layer.

Each layer computes its desires every time the beliefs have changed. In our application we can reduce this to occasions when an intention should be chosen. A new intention is chosen if the current intention is dropped or if there has been no intention. An intention can only be dropped if it becomes impossible or if it is realized. The classification of an intention as impossible is revised after a specified period of time. The stepwise approach is only done by the initiator of a negotiation, but the responder, once it has accepted the request for a negotiation, has got an established issue and partner.[3]

4 INKA-Agents

This section applies the IPS framework to our specific project domain, the shift negotiation based on altruistic relations between agents. We will define the beliefs, desires and intentions at each layer. Additionally, we will describe the procedures how desires are derived from beliefs and how intentions are established.

The model has been implemented in a Java system based on the JADE agent platform[4]. The layered architecture has enabled an incremental development and testing of the system.[5] An agent has two main components: the negotiation module and the system module. The latter one ensures the update of all agent's beliefs at the correct time or when required by the negotiation module. This only applies to beliefs, e.g. shift plan and assumption of social types, that do not directly result from the negotiation process. The architecture of the INKA agents' negotiation module structured by the IPS framework is subject of the next section, while the system module is not described in this paper.

4.1 Issue Layer

Shift utility and concerns. At the issue layer the agent has beliefs that are related to the selection of a work shift as an issue for negotiation. For all shifts of its shift plan the agent has a leisure time interest LTI and a combined evaluation V_S of the different properties a work shift has. Then, the agent a's utility $U_S(a, s)$ of a shift s is defined as $V_S(a, s) \cdot (1 - LTI(a, s))$. It represents the balancing between the value that is associated with the shift and the corresponding leisure time interest.

From these beliefs, which are partly based on the agent's social type the agent derives desires, i.e. a set of concerns that represent shifts the agent would

[3] To avoid conflicts, we require that an agent can become a responder only if it has not done commitments at the issue and partner layers before.

[4] The JADE software is free and distributed by TILAB, in open source software under LGPL (http://sharon.cselt.it/projects/jade/)

[5] In fact, the step layer has been implemented first, and the agents were tested with given issues and partners. Next the agents reasoning on partners has been realized. Finally, all three decisions have been done by the agents.

like to negotiate on. The agent will feel a concern for a shift when the leisure time interest it has for a particular time is above a given threshold.

If an agent feels a concern, then the smaller the utility of a shift is, the stronger is the concern to exchange the related shift: $strength\,(a,s) = 1/U_S\,(a,s)$. This defines an order over all concerns. The strongest concern is selected as the negotiation issue, which is the intention at the issue layer.

If there are concerns that the partner layer has realized not to be able to put forward, they are not considered while selecting the strongest concern as the intention, i.e. as the negotiation issue. If no concern is left, i.e. the agent has no concern to be put forward, then the agent will not look for a negotiation partner and, consequently, it will not start a negotiation until the situation changes.

Passive altruists. At this layer we have not included concepts related to relations or altruism. One might make the concerns dependent on the utility other agents have for a specific shift plan and design agents that actively initiate a negotiation just because somebody else can benefit significantly. We call this an *active altruist.* In our concept, an agent can become at most a passive altruist, i.e. it initiates a negotiation only when it can benefit from a possible exchange, and however, within a running negotiation it behaves in an altruistic way. The concept of passive altruism will affect also the partner layer.

4.2 Partner Layer

For selecting a negotiation partner an agent has beliefs about the possible partners. Possible partners are all other agents that are available for a negotiation and with which the focal agent has not negotiated on the same issue for a given period of time[6]. Additionally, agents have beliefs about the shift plans, as well as beliefs about the relations to other agents and about their social types and the relations to them.

Relation building. An agent maintains relations to agents and to social types, respectively. A relation is represented by a value between 0 and 1. 0 implies a weak while 1 represents a strong relation. If an agent has got positive experiences regarding a certain partner, e.g. a successful negotiation, it strengthens the relation to the partner, as well as the relation to the partner's social type. If the opposite happens, the agent's relations are weakened. Regarding the two types of relations, it is important to realize that with respect to a particular agent both types of relations can be contradictory.

Building relations to classes of agents may be useful when interacting with agents not well known yet. During the first contacts it may be difficult to recognize all properties of the other agent, but it might be possible to put it into a class of agents that describes some group-specific characteristics. In simulations we currently evaluate whether the relations have to be build to individuals only or whether we can get a better performance of agents and/or the whole INKA

[6] This delay prevents that an agents tries to negotiate again and again, hence blocking the other agent and itself.

system by adopting the concept of social types by building relations to social types, too.

Partner utility and partner selection. To each possible partner b of agent a the partner utility $U_A(a, b, s) = U_R(a, b)^{ipr} \cdot U_R(a, Class_A(b))^{isr} \cdot U_{PSP}(a, b, s)$ is assigned. The partner utility depends on the relation the agent has to the other agents $U_R(a, b)$ and to the other agent's social types $U_R(a, class_A(b))$, and it depends on the interest the agent has in the other agents' personal shift plans $U_{PSP}(a, b, s)$. The partner with the highest partner utility is selected as the partner for the negotiation, i.e. as the intention at the partner layer. By defining $U_{PSP}(a, b, s) = \sum_{(s,s') \in PE} U_E(s, s')^2$, with PE as the set of all possible exchanges between the participating agents concerning the issue of the negotiation, we ensure that the agent considers the utility of all possible exchanges but also anticipates that it cannot realize all but only a single exchange. The constants ipr and isr represent the impact of personal and social relations, respectively.[7]

The selection of partners depends on the experience-based relations the agents have, hence we have relation-building agents, but it does not depend on the expected utility for the partners. Thus, as a property of our passive altruistic agents, our agents are not altruistic at the partner layer.

4.3 Step Layer

At the step layer the agent controls the steps it is going to take during the negotiation. It has beliefs about the possible steps during the negotiation, about the utility specific exchanges have for itself, and estimations about the utility the exchanges have for the partner.

The path of a negotiation is restricted by a negotiation protocol as it is presented in Figure 2. This protocol ensures that there is a pre-negotiation dialog where the agents check whether a negotiation is useful (e.g. since the last contact the shift plan has changed) or possible (i.e. the other agent is not busy). In case of a successful negotiation it also prescribes a post-negotiation dialog, which enforces the initiator to request the administration confirming the exchange and to tell the responder about the administration's reaction.

The final sequence of negotiation steps is restricted by the protocol but determined by strategies and tactics that are closely related to a sorted list of possible exchanges. This list contains all exchanges that are allowed and possible between both participating agents, and which have a personal utility above a threshold determined by the social type.

Personal and interactive utilities. For each possible exchange (s, s') an agent a has a personal utility $U_E(a, s, s') = V_E(a, s, s') \cdot LTI(a, s) \cdot (1 - LTI(a, s))$ that depends on the value the exchange has for the agent and on the leisure time

[7] ipr and isr can take values from the interval $[0, 1]$. In case of $ipr = 0$ or $isr = 0$ we define the term as 1, independently of the base, which implies no influence.

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I is the initiator, R is the responder, A is the administration, e and e' are exchanges
1  I:request(R, Negotiation)→R:inform(I, ChangedOrBusy)
2  R:inform(I, ChangedOrBusy)→I:[end] | unnecessary(R) | necessary(R)
3  I:unnecessary(R)→[end]
4  I:necessary(R)→I:propose(R, e) | ultimatum(R, e) | call-for-proposal(R)
5  I/R:propose(R/I, e)→ R/I:propose(I/R, e') | agree(I/R) |
   ultimatum(I/R, e') | cancel(I/R) | call-for-proposal(I/R)
6  I/R:ultimatum(R/I, e)→R/I:agree(I/R) | cancel(I/R)
7  I/R:call-for-proposal(R/I)→R/I:propose(I/R, e') |
   ultimatum(I/R, e') | cancel(I/R) | call-for-proposal(I/R)
8  I/R:agree(R/I)→I:request(A, e)
9  I/R:cancel(R/I)→[end]
10 I:request(A, e)→A:failure(I, e) | inform(I, e)
11 A:failure(I, e)→I:failure(R, e)
12 A:inform(I, e)→I:inform(R, e)
13 I:failure(I, e)→[end]
14 I:inform(I, e)→[end]
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Fig. 2. Negotiation protocol.

interest the agent assigns to both shifts. The value function $V_E(a, s, s')$ weights the benefits of the different properties the two exchanged shifts have.

As we aim to model altruistic agents that do not only derive their behavior from their personal utility, but that anticipate the partner's utility, we define an interactive utility $I_E(a, b, s, s')$ of an exchange (s, s') between agents a and b. The interactive utility depends on the personal utilities of both negotiating agents weighted by an altruism factor: $I_E\left(a, b, s, s'\right) = (1 - \alpha_a) \cdot U_E\left(a, s, s'\right) + \alpha_a \cdot \hat{U}_E\left(b, s, s'\right)$. The partner's personal utility of an exchange can only be estimated by typified utility functions and typified leisure time interests that are assigned to each social type.

Relation-based altruism factor. At the step layer the concept of passive altruism has its most impact. The higher the value of the altruism factor α is, the more an agent's interactive utility depends on the estimation of the partner's personal utility. This factor depends on (1) the relation to the other agent $U_R(a, b)$, (2) the relation to the social type of the other agent $U_R(a, Class_A(b))$, and (3) the impact f of the agents' own social type $Class_A(a)$[8]. We define α_a as $\alpha_a = U_R\left(a, b\right)^{ipr} \cdot U_R\left(a, Class_A\left(b\right)\right)^{isr} \cdot f\left(Class_A\left(a\right)\right)$.[9]

We do not only assign a general altruism factor to each agent but we derive it from a learning process based on dynamic relations specific to each partner and the class (i.e. social type) the partner belongs to. Therefore, the better the past experiences with the partner and with agents of its class are, the higher the altruism factor α is.

Ranked possible exchanges as desires. The interactive utility implies an order over all possible exchanges. If the personal utility is sufficiently high, i.e. above the so-called cancel line, then the higher the interactive utility is, the

[8] Because different social types have a different predisposition to altruism, the own social type influences the altruism factor. Function f assigns each social type a real number that can be interpreted as a specific predisposition of altruism. A value of 0 implies no altruistic behavior while a value of 1 implies full altruistic behavior.

[9] Parameters ipr and isr are the same as in section 4.2

stronger is the desire for a specific possible exchange. Proposals that are below the cancel line at the personal utility lead to a cancel of the negotiation. Proposals that are above this cancel line and are above an accept line at the interactive utility lead to an agreement and can be proposed by the agent. If an agent gets a proposal that is above the cancel line but below the accept line the agent continues the negotiation. The dynamics of the lines during the negotiation process can describe different types of agent reasoning processes, e.g. the impatient, or the patient agent. A graphical representation of this mechanism is provided by Figure 3. This mechanism we call two-scale-based decision mechanism (the two scales are personal and interactive utility).

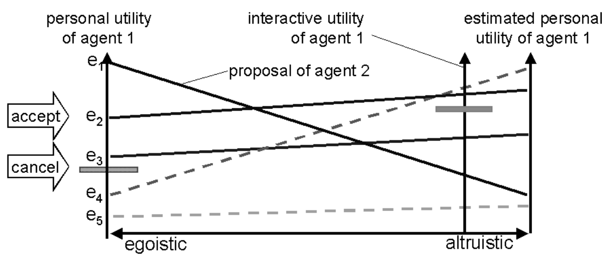

Fig. 3. Two-scale descision making: Each line represents a possible exchange. e_4 and e_5 are removed as they are below the cancel line. Proposal e_1 done by an altruistic agent 2 will not lead to a cancel by another altruistic agent 1 as it would happen with a single-scale-based decision related to interactive utility.

Our first idea to model the reasoning process, i.e. agents only anticipating the interactive utility, has been shown to be inappropriate. When agents accept if the interactive utility of an exchange is above an accept line and cancel a negotiation when it is below a cancel line and additionally agents can become excessively altruistic, we have experienced that the negotiations are cancelled very often, even between altruists. To overcome this weakness [10] suggests that agents cannot become excess altruistic, which would imply $\alpha \leq 0.5$. But we believe that excess altruism can be desirable for agents, e.g. for building relations. Therefore we allow excess altruism. To enable excess altruism but preventing dilemmas between two excess altruists we propose a two-scale-based decision mechanism.

Strategies and tactics In our model, context-sensitive tactics are the base on which an agent selects the negotiation step as intention at the step layer. A strategy is a set of tactics, where a weight can be assigned to each tactic. During each step of a negotiation the agent checks, which tactics are applicable. Tactics without an explicitly assigned weight are only considered when the sum over the weights of all applicable tactics is less than 1. The weights of all tactics to be considered are temporary normalized such that they sum up to 1. From these set one tactic is chosen randomly. The probability distribution is given by the adjusted weights.[10]

[10] In case of many applicable tactics unimportant tactics are inactive, but become active in case of only few applicable tactics.

A tactic depends on the agent's characteristic and on all past steps of the current negotiation. It selects an exchange from the list of ranked possible exchanges and/ or selects a specific performative, i.e. accept, cancel, proposal, ultimatum, or call-for-proposal. We have implemented a simple strategy that contains four tactics: (1) agree and (2) cancel, according to the two-scale-decision making, (3) top-down-proposal and (4) call-for-proposal.[11]

5 Conclusions and Future Work

In this paper we have presented the IPS framework that focuses on the three most important components of the commitment to a negotiation process: issue, partner, and step. The agent's reasoning process deals with all three components. The three layers reflect this requirement. The clear structure of IPS has successfully supported the interdisciplinary communication within the INKA project and it has proven to support an incremental implementation and testing of the MAS. Differences between negotiation architectures become more visible.

In previous work we have introduced the concept of social types that enables agents to deal with other complex agents. Based on this idea we now have extended the concept of altruism, which is used very often in co-operation and co-ordination contexts. We do not only relate it to individuals, but also to social types, and make it dependent on the agent's dynamic social relations. The IPS framework has made it visible that altruism can be approached on all three layers differently. It has led us to the distinction between active and passive altruism. To prevent prisoner's dilemma-like situations of excess altruistic agents we proposed the two scale-based decision mechanism.

The next steps of our work are simulations that explore two questions of sociological and MAS-related interest: What are the properties of specific mixtures of social types and what is the optimal weight agents should assign to relations to classes of agents. Based on these results we will empirically verify the crucial attributes of social types and their impact in real-world negotiations. Subsequently, we will carry out experiments where artificial and human agents are mixed. We want to see whether the agents behave in a socially adequate manner and how the artificial society of agents reacts to humans and vice versa.

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[11] Top-down-proposal starts with proposing the best exchange and continues with the next best. Top-down-proposal and call-for-proposal are applicable in the same situations. The weight of call-for-proposal is given by the social type.

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