A System of Exchange Values to Support Social Interactions in Artificial Societies

Maira Ribelro Rodrigues
PPGC/UFRGS
Porto Alegre, Brazil
mairar@inf.ufrgs.br

A. C. da Rocha Costa
ESIN/UCPel, PPGC/UFRGS
Pelotas, Brazil
rocha@atlas.ucpel.tche.br

Rafael H. Bordini
DCS, University of Liverpool
Liverpool L69 7ZU, U.K.
R.Bordini@csc.liv.ac.uk

ABSTRACT
This paper describes a system of values for modelling social exchanges among agents in artificial societies. The system consists of an algebra of exchange values, a social-reasoning mechanism based on that algebra, and the specification of structures for storing and manipulating such values. The notion of exchange values used here is the one defined in J. Piaget's sociology of small groups, which provides a simple theoretical framework for our endeavour. We show how the system can be integrated with existing interaction models in multi-agent systems. We also illustrate the use of our value-based system by a brief model of the political process of lobbying through campaign contributions.

Categories and Subject Descriptors
I.2.11 [Artificial Intelligence]: Distributed Artificial Intelligence—multiagent systems; I.2.0 [Artificial Intelligence]: General—cognitive simulation; I.4 [Computer Applications]: Social and Behavioral Sciences

General Terms
Design, Experimentation

Keywords
Multi-agent Systems, Social Simulation, Exchange Values, Dynamics of Exchange Values, Value-based Exchange Strategies

1. INTRODUCTION
One of the most relevant yet difficult tasks in modelling interacting agents seems to be the decisions on what are the main social aspects of behaviour and interaction in society. Authors such as Gilbert, Carley, and Newell [11, 3] characterise a social agent as one which not only has distinct knowledge of itself and the others, but also acts based on its representation of the other agents' existence.

This characterisation is somewhat associated with the notion of social structure as a relational structure (the whole collectivity is not identical to the sum of the individuals it contains, but to the sum of the relations between these individuals). An example of such notion can be found in Jean Piaget's sociology of small groups [14]. Alternative notions of social structure can be found, e.g., in [12]. In this work, we investigate the application of Piaget's notion of social exchanges in the context of multi-agent systems.

Piaget follows a theoretical approach to the study of social structures that is based on the conception that social relations are structured around social exchanges, and that the exchanges can be understood from two different points of view. On one hand, exchanges fulfill some purposes, related to the goals of the individuals and/or the society itself. On the other hand, exchanges involve investments, gains and losses of time, money, energy, emotions, expectations, and many other energetic and motivational elements.

To each of such aspects, Piaget assigns some sort of values, resulting from evaluations of the exchanges. Goal values (or ends values) are assigned to exchanges, accounting for their contributions to the goals (ends) of the individuals and/or the society. Performance values are assigned to exchanges, accounting for the variations in the energetic and motivational elements of the exchanges.

It is to the latter type of values that Piaget calls exchange values (in a strict sense), and that we consider in this paper. They are formally defined as qualitative values able to account for motivational and energetic elements of social exchanges. As such, they can be associated with the actions, objects, thoughts, or emotions involved in the exchanges, and thus can influence the behaviour of interacting individuals.

Based on those concepts, Piaget defines a system of values for social exchanges that consists of an algebra of exchange values and a qualitative reasoning mechanism for social reasoning. In this work, we have adapted his definitions aiming at their computational implementation, thus producing a system of exchange values for social interactions in artificial societies and social simulation.

Piaget's theory also defines another important function for exchange values: besides being a means for individual decision-making, Piaget sees exchange values as a regulation tool for guaranteeing the continuity of social interactions, for exchange values imply moral and legal commitments, made by the agents during their interactions. We believe that this latter role of exchange values brings new, complementary meaning and motivation for the work on the dynamics of interactions among artificial agents. Thus, we use exchange values both as motivational elements in the interactions between agents, and as regulatory elements with respect to the equilibrium and the continuity of their exchanges. To the best of our knowledge, this is the first attempt to explore such fundamental ideas in the context of social interactions in multi-agent systems.
Our work is also motivated by our sharing the opinion of Miceli and Castelfranchi [13] that the explicit representation of values is an important aspect in the study of planning, decision making and other forms of social interactions among agents. Thus, it is an important aspect for multi-agent systems in general. In order to show how our system of exchange values can also be applied to real-world situations, we present briefly the dynamics of values in the political process of lobbying through campaign contributions.

This paper is structured as follows. The next section presents some related work on the notion of values in the context of multi-agent systems. Section 3 provides an overview of Piaget’s theory of exchange values, which provides a simple theoretical framework for our endeavour. The system of exchange values and the specification of the structures that support it are described in Section 4. The social reasoning mechanism based on exchange values is presented in Section 5. In Section 6, we show how the system of exchange values can be integrated with existing interaction models. Section 7 provides a sample application of the system where we try to model, in a simplified way, the dynamics of values in the political process of lobbying. Finally, we present some conclusions and ideas for future work in Section 8.

2. RELATED WORK

Work on multi-agent systems have made extensive use of ends values. For instance, building on economic theories, there is a whole line of research influenced by game theory [16] and decision theory [2], modelling ends values in a utilitarian, quantitative way.

Another line of research in multi-agent system, inspired by the cognitive and social sciences [6], has often opposed the utilitarian approaches mentioned above. They argue, for example, that such rational decision making (in the economic sense) does not account for all the complex social relations observed in human societies. In contrast, they seek to shed light on the intricate relations between cognition and social structures in artificial societies [5].

It is arguable, however, that the latter approach lacks some of the features provided by the utilitarian approaches for the design of multi-agent systems. In general terms, one of the missing points in the socially inspired work on multi-agent system is a practical regulatory system accounting for the continuity of social exchanges.

This paper contributes towards the design of such regulatory system, in the approach suggested by the Piagetian notion of exchange values. Note that the qualitative nature of Piaget’s notion of values suits particularly well the work on socially embedded cognitive (symbolic) agents, as opposed to the quantitative notions of values used by the utilitarian approaches.

Following the line of research inspired by the social sciences, certain other notions of values have also appeared in the multi-agent systems literature. Miceli and Castelfranchi [13], for instance, deal with the cognitive role of evaluations and values. This approach assumes that values are a special kind of evaluation that mediates beliefs and goals in the agents’ knowledge representation. Antunes and Coelho [1] use a notion of “multiple values” to improve agents’ decision-making process by explicitly including these values in their agent architecture — the BVG architecture.

Although the references given above relate in one way or another to some conception of values, either they do not encompass the idea of exchange values, or they do not have the moral commitment implications of that notion of values, a feature that is central to Piaget’s approach, and which provides the basis for the model of interactions presented here.

Dignum [8] has done work on norms and values in a way that seems rather complementary to our approach, in that they clearly focus on the legal aspects of interactions and their goals, while we focus on the moral aspects of interactions and the subjective investments and social commitments they imply.

3. PIAGET’S THEORY OF EXCHANGE VALUES

Piaget defines values in a twofold sense [14]. On one hand, a value is “anything that can give rise to an exchange”. The values involved in an exchange, in this sense, are not only material objects, but may also be actions, ideas, emotions, social habits, etc. On the other hand, a value is the result of a qualitative mental evaluation of the elements involved in the interactions, each resulting value being mentally associated to one such element. Note that values in this second sense — taken as motivational objects — are also values in the first sense, that is, elements that can give rise to exchanges.

To narrow the focus, so that a formalisation was possible, Piaget centred his attention on the analysis of a special kind of exchange, namely, the exchange of services between individuals, i.e., actions that an individual performs on behalf of another individual. The values that result of such exchanges can be seen as moral values, concerning moral debts (i.e., the moral obligation to perform new services in return to services previously received) and moral credits (i.e., the right to demand the performance of new services in return to services previously given).

One important characteristic of Piaget’s notion of exchange values is that exchange values are of a qualitative nature, quantitative values appearing only in the particular case of the modelling of exchanges involving economic values. So, in our system of exchange values, every service that an individual agent performs for another agent, or every service from which it gets some benefit, is associated by the agent with some positive or negative qualitative value. As such, these values can influence the agent’s behaviour in future exchanges.

Piaget’s theory assumes two conditions for the existence of an exchange value system:

- the individuals involved in an interaction must share a common scale of values, to ensure the compatibility of their evaluations of performed and received actions (services);
- conservation of the exchange values in time: if there is no conservation of the values in time (i.e., values can suffer depreciation), this fact can risk the continuity of the interactions, and of the functioning of the whole society. Such conservation of values can be achieved by a system of rules (i.e., a normative structure) having two types of rules: moral rules and legal rules.

If these two conditions hold, a system of exchange value can be seen as a mechanism for regulating (coordinating) the social exchanges of services between agents, guaranteeing their continuity (and, thus, the continuity of the functioning of the society).

Complete exchanges between individuals occur in two stages whose basic forms are as follows: (I) an individual, say $\alpha$, performs an action on behalf of another individual, say $\alpha'$, acquiring some credit for that action; and (II) $\alpha$ claims his credit asking $\alpha'$ to perform some action for him, in return. When $\alpha'$ performs that action, the exchange is complete. The event sequence for the two stages of a basic social exchange between $\alpha$ and $\alpha'$ are shown in Figure 1. The first stage consists of four steps (see Figure 1(a)):

1. $\alpha$ performs a service on behalf of $\alpha'$ and associates with this action a renouncement value ($r_\alpha$), representing his investment in the action (time, energy, money, emotional expectations, etc.);
2. \( \alpha' \) expresses his satisfaction with the received action associating to it a satisfaction value \((s_{\alpha'})\);
3. \( \alpha' \) acknowledges the value of the received action by expressing the acknowledgement value \((t_{\alpha'})\);
4. \( \alpha \) feels (personally or socially) valued with the acknowledgement of \( \alpha' \), and associates to it a reward value \((v_{\alpha})\).

At the end of the first stage, the individual \( \alpha' \) has acquired a debt \((t_{\alpha'})\) with individual \( \alpha \), and \( \alpha \) acquired a credit \((v_{\alpha})\) with \( \alpha' \).

Later on, \( \alpha \) can claim his credit with \( \alpha' \) by requesting that \( \alpha' \) performs some service in return (a service that will benefit \( \alpha \)). This gives rise to the second stage of the exchange process (see Figure 1(b)):
1. \( \alpha \) requests that \( \alpha' \) performs an action on his behalf, based on the credit \((v_{\alpha})\) that \( \alpha \) has in relation to \( \alpha' \);
2. \( \alpha' \) acknowledges the debt \((t_{\alpha'})\);
3. \( \alpha' \) performs a service with a renouncement value \((r_{\alpha'})\);
4. \( \alpha \) acknowledges his satisfaction \((s_{\alpha})\) with the service performed by \( \alpha' \).

Piaget calls \( r \) and \( s \) the real values involved in the interaction — values resulting from the evaluation of the real actions occurring during the interaction — and calls \( t \) and \( v \) the virtual values involved in the interaction — values corresponding to debits and credits that are to be turned into real values in future interactions.

![Figure 1: Sequence of Events in the Exchange Process.](image)

During the sequence of events in an exchange stage, the exchange values accumulated by the individuals suffer increments and decrements (positive or negative variations). If the total sum of the variations during a certain stage is null, the system is said to be in equilibrium with respect to the exchanges occurring at that stage.

Representing a positive variation of exchange values by prefixing the corresponding individual with ‘\( \dagger \)’, and a negative variation with a ‘\( \ddagger \)’, the equilibrium situations for the first and second stages of the exchange process are represented by the following equations:

- **Stage I** \((\dagger \ r_{\alpha} \dagger) + (\dagger \ s_{\alpha}) = 0\)
- **Stage II** \((\dagger \ t_{\alpha}) + (\dagger \ v_{\alpha}) = 0\)

Piaget observes that nonequilibrium situations may arise for various reasons, and may occur in any step of the exchange process. For example, when \( \alpha' \) — for any reasons — expresses a wrong value \((t_{\alpha'})\) for the satisfaction \((s_{\alpha'})\) he had with the initial service provided by \( \alpha \), or when \( \alpha' \) underpays \((r_{\alpha'})\) the debt \((t_{\alpha'})\) he had acknowledged \( \alpha \) to (see [14] for a thorough analysis of all possible nonequilibrium situations).

Besides the internal equilibrium within each stage, Piaget observes that a system’s equilibrium depends on the equilibrium during the succession of the two stages as well. In other words, if in the first stage agent \( \alpha \) is exchanging real values for virtual values, and in the second stage he is exchanging virtual values for real values, then for a system’s equilibrium to be maintained one must ensure that the virtual values remain the same when the agents pass from stage I to stage II. Therefore, the system must provide the means for the conservation of the exchange values, both when going from one step to the next within a stage, and when going from one stage to another, if the overall equilibrium and continuity of the exchange processes is to be guaranteed.

For Piaget, that is precisely the role played by the various social means for value conservation called normative structure. This structure is a set of rules, of various types (of both moral and legal natures), established in various ways (e.g., centralised legal systems, mutual local agreement, private contracts, personal commitments).

It is important to note that Piaget’s theory was developed with a focus on fixed social structures (the so-called synchronic approach), not on evolving social structures (the diachronic approach), and our present work lies within that scope limitation.

### 4. A SYSTEM OF EXCHANGE VALUES FOR MULTI-AGENT SYSTEMS

According to Piaget’s theory, in our system agents store four types of values: renouncement \((t)\), satisfaction \((s)\), acknowledgement \((r)\), and reward \((v)\). So, for each interaction in which an agent \((\alpha)\) participates, it stores an array of exchange values associated with the other agent involved \((\alpha')\); that array is called \( V_{\alpha'\alpha} \).

Along the various exchange processes, those values can suffer variations and can be decreased or increased. This suggests the need for an algebra of operations on exchange values, which we sketch below based on [14].

#### 4.1 Representation, Storage, and Manipulation of Exchange Values

In order to have an appropriate representation for exchange values and their operations, we follow established practices in the area of qualitative reasoning [10]. We take a simplified value set for exchange values, namely the integers \(\{\ldots, -2, -1, 0, 1, 2, \ldots\}\), and we define that each increase or decrease of an exchange value during a single step of an exchange process changes that value by an integral number of units, \(\pm n\) or \(-n\), according to certain criteria.

Despite the formal quantitative appearance of such representation, it should be clear that it will be used in a qualitative way, due to restrictions on the operations allowed on them: under no circumstance the amount of the difference between two exchange values \((x_1 - x_2)\) shall be needed in the reasoning processes, only the information on their relative magnitudes \((x_1 > x_2, x_1 = x_2, x_1 < x_2)\), which makes clear the qualitative (order-theoretic) nature of the way in which such values are to be handled.

Considering the two basic stages of an exchange process, starting with agent \( \alpha \) performing a service to agent \( \alpha' \), we can define the general ways in which the exchange values are allowed to vary. We assume that each agent \( \alpha \) has an array \( V_{\alpha'\alpha} = (r; s; t; v) \) representing the state of the set of its exchange values that are involved in exchanges with agent \( \alpha' \). Then, we define \( \Delta r V_{\alpha'\alpha} \) and \( \Delta t V_{\alpha'\alpha} \) to be the arrays representing the ways the exchange values of agent \( \alpha \) vary when it interacts with agent \( \alpha' \), and \( \Delta t V_{\alpha'\alpha} \) and \( \Delta t V_{\alpha'\alpha} \) to be the arrays representing the ways the exchange values of agent \( \alpha' \) vary in those interactions; they are defined as follows:

#### Stage I:

\[
\begin{align*}
\Delta r V_{\alpha'\alpha} &= (\Delta r = -m_t; \Delta s = 0; \Delta t = 0; \Delta v = +n_t) \\
\Delta t V_{\alpha'\alpha} &= (\Delta r = 0; \Delta s = +m_t; \Delta t = -m_t; \Delta v = 0)
\end{align*}
\]
Stage II:
\[ \Delta y V_{\alpha,0} = \{ \Delta r = 0; \Delta s = \pm m_{12}; \Delta t = 0; \Delta v = -n_{12} \} \]
\[ \Delta y V_{\alpha,1} = \{ \Delta r = -m_{12}; \Delta s = 0; \Delta t = +m_{12}; \Delta v = 0 \} \]
so that, after the first stage of an exchange process, the value \( \Delta_y V_{\alpha,0}(v) \) represents the increase in the credit \( V_{\alpha,0}(v) \) that \( \alpha \) has in relation to \( \alpha' \), awarded to \( \alpha \) during that stage. In the same way, \( \Delta_y V_{\alpha,1}(t) \) represents the increase in the debt \( V_{\alpha,1}(t) \) that \( \alpha' \) has with respect to \( \alpha \), attributed to \( \alpha' \) during that stage. Then, after each stage of exchange, the arrays \( V_{\alpha,0} \) and \( V_{\alpha,1} \) should be updated with the corresponding \( \Delta_y V_{\alpha,0} \) and \( \Delta_y V_{\alpha,1} \).

As noted above in Section 3, Piaget’s algebra of exchange values assumes the existence of a common scale of exchange values among the agents involved in the interactions. The definition of this scale depends on the particular application context in which the model is being used.

Finally, it is important to mention that the basic sequence of stages (I \( \rightarrow \) II) can also be performed the other way around (II \( \rightarrow \) I), with agent \( \alpha \) acquiring initially a debt and agent \( \alpha' \) a credit.

4.2 Complementary Structures

We assume that agents have access to certain information about other agents and the society, either in the form of an explicit representation found somewhere in the society or in the agents themselves, or in the form of beliefs the agents develop as they operate in the society. To enable agents to reason about the exchange values present in the society, they must have access to (at least) the following information:

- **The composition of the society**: the agents, their goals and plans, and the actions they are capable of performing (as the external description used in [17]).
- **The exchange-value variation array**: the arrays of variations of the exchange values during the current exchange (\( \Delta_y V \) and \( \Delta_t V \)).
- **The state of exchange values**: the set of exchange values (\( V_{\alpha,0} \) or \( V_{\alpha,1} \)) accumulated by the agents along the exchanges with other agents. With this information, agents can identify mutual credits and debts with the various agents. As this information is cumulative, it must be updated after each exchange process with the information in the variation arrays.
- **The history of exchange values**: each entry should contain the time when the exchange took place, the action performed or received by agent \( \alpha \), the identification of agent \( \alpha' \) involved in the exchange, and the variation array associated with the exchange. This information enables a long term analysis of the dynamics of exchange values during the simulation. Also, having a history of exchange values allows the agents (or external observers) to retrieve useful information from it, such as what services (from the set of services an agent is capable of performing) were better valued by some other agent at a given time.
- **The set of norms and agreements**: this is established during the exchange process in order to reach an agreement on the operations that guarantee the conservation of the exchange values in time.
- **The exchange-value strategies**: the set of rules and criteria used by the agent to choose among potential partners for social exchanges, and to elaborate interaction proposals that result in a desirable next state of exchange values. An agent’s behaviour is (partly) determined by its exchange-value strategy, and different exchange-value strategies may exist among the various agents in the society.

5. A SOCIAL-REASONING MECHANISM BASED ON EXCHANGE VALUES

We now show how the proposed system defined in the previous section can support a social-reasoning mechanism based on exchange values. The social-reasoning mechanism we describe here is directed towards supporting what seems to be the two main goals of introducing exchange values in multi-agent systems, namely: the formulation of legal rules and moral norms contributing to the equilibrium of the exchange values in the society (and to the continuity of such exchanges), and helping agents to develop and make use of exchange-value strategies directed towards guiding their planning and decision making with respect to exchange processes.

The social-reasoning mechanism operates in three phases: before the exchange, during the exchange and after the exchange. The state diagram of the whole value-based social reasoning mechanism is shown in Figure 2.

![Figure 2: State Diagram of the Social-Reasoning Mechanism.](image)

**Reasoning Before the Exchange**

An agent in a multi-agent system can initiate an exchange, and so activate its value-based social reasoning mechanism, for following reasons: (i) the agent is not capable of performing an action needed for executing a plan that achieves a goal to which it has committed, thus requiring that another agent performs that action as a service; (ii) the agent is capable of performing the actions needed to execute the plans for its goals, but would prefer that another agent performed it as a service; (iii) the agent does not need any action at the moment — its current plans are independent of the other agents — but intends to earn credits on other agents by offering them some service.

The reasoning mechanism in this phase is an extension of the cognitive model of social reasoning proposed by [7], with the addition of a computation based on exchange values. We have also extended this combined mechanism so that it can work not only with the dependence-based model, but also with the contract net model. As a result, we have a unified mechanism that can be mapped onto both models.

Given the agent’s motivation and state of exchange values, the social reasoning before the exchange consists of a computation that is instrumental for the agent to decide (in accordance with the agent’s strategy): (i) which agents and types of exchange proposals suit best the target exchange, and (ii) which agents are more likely to accept the proposal. The chosen proposal is the one that results in the most desirable next state of exchange values according with the agent’s exchange-value strategy. For example, if the desired next state is a positive one, then the agent’s next interaction must
result in a positive state of exchange values (i.e., the agent acquiring credits with other agents), whereas interactions resulting in a negative state of exchange values (i.e., acquiring debts with other agents) must be avoided.

We define four basic types of exchange proposals, as follows.

**Type 1** – Requesting a service in exchange of another service. Here the agents follow the first and second stages of the exchange process (Figure 1(a) and (b)).

**Type 2** – Requesting a service in exchange of a credit. Here the agents follow the first stage of the exchange process (Figure 1(a)). After the exchange process the agent that requested the service acquires a debt, and the agent that performed the requested service acquires a credit that later can be claimed back. In this case the agents would probably want to reach an agreement on which rules will ensure the conservation of the acquired exchange values.

**Type 3** – Requesting a service in exchange for a previously acquired credit. Here the agents follow the second stage of the exchange process (Figure 1(b)). In this case the proponent will be claiming a credit acquired in a previous exchange, and it expects to acquire a debt. In this case too the agents would probably want to reach an agreement on which rules will ensure the conservation of the acquired exchange values.

**Type 4** – Offering a service in exchange of a credit. Here the agents follow the first stage of the exchange process (Figure 1(a)). In this case the agent that offers the service acquires a credit and the agent that accepts the offer (e.g., receives the offered service) acquires a debt. In this case the agents would probably want to reach an agreement on which rules will ensure the conservation of the acquired exchange values.

The sequence of reasoning states in the proponent’s (α) social reasoning before the exchange, as seen in Figure 2, is as follows.

1. **Identify the motivation for the exchange.**
2. **First computation of exchange values.**
   (a) Choose the possible partners for the interaction, depending on the motivation of the agent and the criteria defined in the agent’s strategy. This results in a set of possible partners.
   (b) Choose the type of proposal associated with each selected partner and sort the set of possible partners according to some criteria established in the agent’s strategy.
   Examples of possible associations are: associate proposal type 3 to agents with which the proponent has credits; associate proposal type 2 to agents on which the proponent depends for a certain service and with which it does not have credits; and so forth.
   (c) Elaborate the exchange proposal. For each possible partner, the proponent must elaborate a proposal containing the following fields (whose names are self-explanatory): (i) type-of-proposal, (ii) type-of-service, and (iii) suggested-norms.
3. **Send the exchange proposal.** Depending on the interaction model onto which the exchange model is being mapped, the proponent sends a proposal to a single agent from the set of possible partners, or sends proposals to all agents in that set (Msg1). The dependence-based model requires the proponent to send a message to only one agent, whilst the contract net model requires the proponent to send more than one message, normally to all agents in the society.
4. **Wait for a reply.** The proponent waits for replies with a certain threshold on waiting time. When the waiting time expires, or replies are received, the agent passes to the next step. Again, the implementation of this step depends on the model onto which the exchange model is being mapped. When using the dependence-based model, the agent will probably receive more than one reply, so it should wait until a certain number of replies are received.

5. **Analyze the situation:** (i) if the proponent has not received any replies, or has received only negative replies, and the set of possible partners is empty, then it must revise its strategy and start the whole process again; (ii) if the proponent has not received any replies, or has received only negative replies, and the set of possible partners is not empty, then it must return to state 3 and send the proposal to another agent chosen from that set; (iii) if a request claiming a credit (proposal of type 3) receives a negative reply, the proponent can request the compensations or enforce the punishments as established in the norms associated with the proposal that originated the credit; (iv) if the proponent receives one or more positive replies (Msg2), it passes on to the next state.
6. **Second computation of exchange values.** In this state the proponent must choose an agent among those that have accepted the proposal, and check whether they have agreed with the proposed norms or whether a counterproposal was made.
7. **Send the acknowledgement to the selected partner (Msg3).**
8. **The exchange process begins.** The social reasoning mechanism passes to the next phase (reasoning during the exchange).

When the exchange model is mapped onto the dependence-based model, the main social reasoning process occurs in state 2 of the protocol (i.e., the first computation of exchange values). That is because in the dependence-based model the agent must reason about its possible interaction partners before sending the coalition proposal. On the other hand, when the exchange model is mapped onto the contract net model, the main social reasoning process occurs in state 6 of the protocol (i.e., the second computation of exchange values). The reason is that, in the contract net model, an agent is supposed to send coalition proposals to several agents and the decision on the most suitable partner is made when the replies are received (further discussion on this issue is given in Section 6).

When an agent receives a proposal, it can use the same social reasoning mechanism to decide whether it should accept the proposal or not. In other words, the agent will accept a proposal if it leads to the most desirable next state of exchange values, according to the agent’s exchange-value strategy. The sequence of reasoning states for the recipient (α') is as follows.

1. **The agent is prepared for receiving messages.** When it receives a message (Msg1), it activates the value-based social reasoning mechanism and passes to state 2.
2. **Computation of exchange values.**
   (a) Select the acceptable proposals, which depends on the criteria defined in the recipient’s strategy. This step results in a set of potential partners.
   (b) Sort the selected proposals. If more than one proposal was received, the agent must sort the set of potential partners according to the criteria established in its strategy. In case the agent receives a proposal of type 4 (offering a service), it must analyse if the offered service is in fact useful at the time. If it is not, the agent can counter-propose another service. Also, in this step the agent must analyse the regulations (i.e., the norms) proposed by the proponent. If the agent does not agree with them, it can counter-propose the adoption of different norms when replying.
(c) Elaborate the reply message. The agent associates a positive answer with the agents in the set of potential partners and a negative answer with the other ones. The reply messages must contain the following information: (i) answer (yes/no/counterproposal), (ii) action (accepted/counter-proposed), and (iii) norms (accepted/counter-proposed).

3. Send the reply message (Msg2). The agent sends a positive reply to the agent from the set of potential partners whose proposal seems to lead to the best state of exchange values, and sends a negative answer to the agents that were excluded from that set in the previous step.

4. Wait for the acknowledgement. The recipient waits a certain time for the acknowledgement. When the time expires or the acknowledgement (Msg3) arrives, the agent passes to the next state.

5. Analyse the situation: (i) if the agent has received no acknowledgement message and the set of potential partners set is empty, return to the initial state; (ii) if the agent has received no acknowledgement message but the set of potential partners is not empty, it returns to state 3 and sends a new positive answer message to the next agent in the set; (iii) if the agent has received an acknowledgement, the exchange process begins and the social-reasoning mechanism passes to the next phase (reasoning during the exchange).

Reasoning During the Exchange

In this phase the exchange of actions take place. The sequence of events depends on the type of proposal agreed upon by the agents and follows the order established in stages I or II of the exchange process (see Figure 1, Section 3).

During the exchange, the social reasoning of the agents involved consists of computing the variation of the exchange values, represented by the arrays $\Delta_1 V^\alpha_{n,n'}$ and $\Delta_2 V^\alpha_{n,n'}$ for agent $\alpha$, and $\Delta_1 V^{\alpha'}_{n,n'}$ and $\Delta_2 V^{\alpha'}_{n,n'}$ for agent $\alpha'$.

As defined in Piaget’s theory, the variations in the exchange values can be positive or negative, depending on the type of exchange value and on which agent performed or received the service.

Reasoning After the Exchange

After the exchanges have been performed and the variations in the exchange values have been computed, the social-reasoning mechanism proceeds by updating the agents’ exchange-value structures: the state and the history of exchange values. Also, the agents must store in their data structures the set of norms or agreements upon which they have agreed before the exchange, so that they are aware of their duties and rights in future exchanges.

6. INTRODUCING EXCHANGE VALUES INTO EXISTING MODELS OF INTERACTION

This section illustrates how existing models of interaction can be enhanced with a value-based social reasoning mechanism. We have chosen two practical models of dynamic organisations — the Contract Net [18] and Dependence-based Coalitions [17, 7] — in order to show how that can be done.

Those models were chosen because they focus on the exchange of services: agents perform services to, and receive services from, other agents in the society for achieving individual or collective goals. Also, the dependence-based model has the advantage of incorporating a more elaborate social conception (the society is structured on the basis of dependence relations), whereas the contract net model has the advantage of having been widely applied and discussed in multi-agent systems literature.

Figure 3: State Diagrams for the Three Models.

The event sequences for the three models are shown in Figure 3. It is interesting to see that the value-based interaction model combines the reasoning and communication processes of the two other models and at the same time tries to retain the differences between the models. For example, while the dependence-based social reasoning mechanism use the concept of dependence [4] to motivate the agents’ interactions, in the contract net model the agent’s incentive to cooperate with others is coded into the system (i.e., agents are not autonomous). As a consequence of that combination, when the value-based interaction model is mapped onto each of them, their individual characteristics are maintained.

Thus, when the value-based interaction model is mapped onto the dependence-based model, the agent’s social reasoning occurs before the sending of the coalition proposal (Msg1), and takes into account the dependence relations and the exchange values. When the value-based interaction model is mapped onto the contract net model, the agent’s social reasoning occurs after receiving the bids (Msg2) and takes into account only the exchange values.

Some of the contributions of the reasoning based on exchange values to the dependence-based model are presented in Table 1. Note that what is argued in item (a) of the table can account for certain social interactions (often observed in human societies) that would not be possible in the original model. The contributions to the contract net model are not explicitly given here, but are very similar to those in the table.

7. AN EXAMPLE APPLICATION

In this section we use our system of values to model, in a simplified way, the political process of lobbying through campaign contributions. We have chosen the lobbying process because it is a clear example of the ubiquitous processes involving exchange of values between individuals in a society. The exchanged services (or actions) can be material ones (e.g., monetary contributions, presents, votes) or subjective ones (e.g., promises, faithfulness, gratitude gestures).

In modelling that scenario, we have distinguished three types of agents: politicians, lobbyists, and voters. The social context in which they are embedded is a political election, and each of them has its own goals and interests in relation to resource destination alternatives. The scenario is characterised by two different situations: before the election (the campaign situation) and after the election.
Table 1: Comparison Between Dependence-based and Value-based Reasoning.

<table>
<thead>
<tr>
<th>Dependence-based</th>
<th>Exchange Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Provides technical motivations or practical reasons for the interactions. The agent only takes the initiative to interact with other agents when it observes a dependence relation between them.</td>
<td>(a) Provides more subjective reasons for the interactions, aiming at their continuity. The agent takes the initiative to interact with other agents even if it has not observed any dependence relation between them, since it takes into account its exchange values state during the social reasoning process.</td>
</tr>
<tr>
<td>(b) The reasoning is not directed to the continuity of interactions since the agents do not assume any commitment with each other after the interactions.</td>
<td>(b) The reasoning is directed towards the continuity of the exchange process since the credits and debts acquired by the agents are seen as (persistent) social commitments.</td>
</tr>
<tr>
<td>(c) The social power relations are based on the practical actions of the agents. So, if the abilities of the agents do not change during the simulation, these relations remain static and do not evolve with the results of the interactions.</td>
<td>(c) The social power relations are based on the agents’ states of exchange values. They are dynamic and are modified according to the results of the interactions.</td>
</tr>
</tbody>
</table>

For the sake of space, only a brief analysis of the scenario is given here (see [15] for a more comprehensive analysis).

7.1 The Normative Structure

For simplicity, in this scenario we consider a normative structure (set of legal rules and moral norms) with only one moral norm to guarantee the conservation of the exchange values (referred to as norm1). According to it, every agent that receives a proposal claiming a credit (type 3) has the deadline of three time units to perform the required service in return. The punishment for not complying with the norm is the depreciation of the reward value that the noncomplying agent will experience in future interactions.

7.2 Description of the Agents

The Political Agent

Goal: Its goal is to win the political election. It makes choices on resource destination, considering what it believes to be more appropriate to the development of the community as a whole. At the same time, the politician has to consider whether the choices are in agreement with the interests of particular groups (represented by the lobbying agents) and of the general population (the voters), with the intention of receiving in exchange votes and financial contributions to the political campaign that are necessary for the political agent to achieve its goal.

Desired state of values: Usually, negative or null before the election and positive after the election. A negative or null state of values indicates that the politician received some services from other agents (lobbyists or voters) either by requiring these services in exchange of some credit, or by claiming them in exchange for previously acquired credits. This may be a good situation before the election, given that these services represent, for example, financial contributions to the campaign or voting intentions. A positive state of values after the election indicates that not only has the political agent repaid its debts (acquired before the election) with lobbying and voting agents, but it has also gained some extra credits with these agents by performing services on their behalf.

Strategies to achieve the desired state of values: In this scenario, we can identify two types of strategies: one based on credits, and the other based on debts. The strategies capture real-world situations, the first where a politician supports his campaign on his past achievements, when he gained prestige and recognition with voters and lobbyists (credit-based strategy); and the second where the politician supports his campaign on promises of great achievements (debits-based strategy). In order to use the first strategy, the agent must have an initial positive state of exchange values (i.e., credits with lobbyists and voters), and should send exchange proposals of type 3. The second strategy must be used when the agent has a negative or null state of exchange values (i.e., no credits with lobbyists and voters). It indicates that the agent should send exchange proposals of type 2.

The Lobbying Agent

It represents the interests of a particular group of people (e.g., big companies or another political party). The lobbyist’s goal is to influence the politicians to choose a particular destination of resources by offering them financial contributions to be used in the political campaign. The lobbying agent’s desired state of values is positive before the election (i.e., credits with political agents) and negative or null after the election (i.e. he claimed the acquired credits in exchange of desired courses of action). The strategy it uses to achieve the desired state of values is to offer financial contributions to (and request political favours from) political agents.

The Voting Agent

It is the politician whose proposals on resource destination are best suited for its interests and the interests of its community. The voting agent’s desired state of values is positive before the election (i.e., credit with the political agent) and negative after the election (i.e., it has claimed its credit with the political agent in exchange of some desired course of action). The strategy used to achieve the desired state of values is to accept requests for service (probably the voting intention) from — and offer the voting intention to — the political agents.

Several aspects of the agents’ behaviour can be captured by the analysis of the information on exchange values. Some of them may be incorporated into the agents’ strategies to help them in the choice of the best partner for an exchange. Examples are:

1. the fidelity of the voter with respect to the politician (by analysing the voting agent’s history of exchange values); 2. the politician’s commitment to lobbying agents (by analysing the political agent’s history and state of exchange values); 3. the politician with the most voting intentions (by analysing the political agent’s state of exchange values); 4. the services that are most required by voters and lobbyists (by analysing the political agent’s history of exchange values).

7.3 A Sample Reasoning Based on Exchange Values

We now show a simple example of the activation of the proposed social reasoning mechanism in a prototypical phase of an interaction. Let us suppose that the lobbyist agent L1 receives a proposal
from the political agent \( P_1 \), asking for funding in exchange of a future political favour. A possible part of the lobbying agent’s social reasoning is as follows:

1. Receiving a proposal:
   \[
   \text{proposal(type}\_2, \text{contribution}=300.00, \text{norm}1); \]
2. Computation of exchange values: (a) Selection: OK (proposal type 2); (b) Sorting of potential partners: \( P_1 \); Norms: OK; (c) Elaborating the reply message: answer\{yes, accepted, accepted\};
3. Sending the message to \( P_1 \);
4. Waiting for the acknowledgement;
5. Analyse the situation: acknowledgement received;
6. Performing the exchange process. The sequence of events follow the Stage I of the exchange process, with agent \( P_1 \) receiving the service (contribution=300.00) from agent \( L_1 \). Computation of the array of exchange-value variation: \( \Delta V_{L_1, P_1} = \{ r = -1; s = 0; t = 0; v = +1 \} \) and \( \Delta V_{P_1, L_1} = \{ r = 0; s = +1; t = -1; v = 0 \} \).
7. After the exchange: updating the agents’ exchange-value structures with the results in \( \Delta V_{L_1, P_1} \) and \( \Delta V_{P_1, L_1} \). Agent \( P_1 \) must add a positive variation to its satisfaction value \( s \), and a negative variation to its acknowledgement value \( t \) in the table entry associated with agent \( L_1 \). On the other hand, the agent \( L_1 \) must add a negative variation to its renunciation value \( r \), and a positive variation to its reward value \( v \) in the table entry associated with agent \( P_1 \).

As a result of the exchange, agent \( P_1 \) has acquired a new debt \( (\Delta V_{P_1, L_1}(t)) \) with \( L_1 \), and \( L_1 \) acquired a new credit \( (\Delta V_{L_1, P_1}(r)) \) with agent \( P_1 \). If \( P_1 \) is elected, \( L_1 \) can claim the previously acquired credit asking \( P_1 \) to perform some service on its behalf, such as destining governmental resources in a way that favours the lobbyist personal interests; that is, the lobbying has been successful. The same situation may occur with a voting agent that has a credit with the elected politician and wants to claim it back, for instance by means of governmental investments in the local community.

One can see that, by monitoring the evolution of the exchange values of political agents that have been successively re-elected along a series of elections, and the corresponding periods of governmental activity, their tendency to fulfill commitments with either voters or lobbyists can be checked, and the net debts and credits that were acquired can be adequately worked out.

8. CONCLUSIONS AND FUTURE WORK

We have presented an approach to social reasoning, based on Piaget’s notion of exchange values, that supports complex agent interactions in artificial societies and social simulations. It consists of a qualitative social reasoning mechanism and of specifications of data structures and operations for handling exchange values. We have argued that this approach can improve the modelling of social agents’ interactions by capturing moral aspects of such interactions. Moreover, the proposed system of values also provides a practical social regulatory system that allows for a reasoned continuity of social exchanges.

Combined with a system of norms and values concerned with the legal aspects of interactions and their goals (as, for instance, the system described in [8]), the system of exchange values introduced here — which is concerned with the moral aspects of social exchanges — may support a social reasoning mechanism able to cope with a great deal of the objective and subjective aspects of social interactions in artificial societies. Investigating how to combine our system of exchange values with the notion of social plans for BDI agents [9] is also something that we plan to do.

9. REFERENCES


