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Formalizing Interchange Competences

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ABSTRACT

An important aspect in multi-agent cognitive systems is being able to provide negotiation facilities to agents. In this article we deal with this problem by presenting a formal environment allowing to specify preferences. Moreover, our framework describes how to perform exchanges among the entities involved in the system. The exchanges are not restricted to material goods, as we introduce capabilities to deal with intangible goods. The description of the system is formalized by using a simple process algebra that allows dealing with entities organized in a hierarchical way.

Keywords: *Cognitive Informatics, Functional Languages, Learning, Simulators*

FORMALIZING INTERCHANGE COMPETENCES

One important part of cognitive processes is decision making. As defined in (Wang, & Ruhe, 2007), "decision making is a process that chooses a preferred option or a course of actions from among a set of alternatives on the basis of given criteria or strategies". Obviously, decision making is also a complex issue itself, requiring different types of techniques for the different aspects it requires. In this article we will concentrate on developing a formal framework to describe the exchange of goods (either material or intangibles) among entities, assuming that each entity can describe its own preferences.

In particular, our approach will be based on using an agent-based system. The reason is that these systems have already proved their usefulness to deal with cognitive environments (see e.g. (Yang, Lin, & Lin, 2006; Vinh, 2009; Uchiya, Maemura, Hara, Sugawara, & Kinoshita, 2009)).

In our work, the concept of utility function is very useful. A utility function returns a real number for each possible basket of goods: The bigger this number is, the happier the owner is with this basket. Intuitively, agents should act by considering the corresponding utility function

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(see e.g. (Rasmusson & Janson, 1999; Eymann, 2001; Dastani, Jacobs, Jonker, & Treur, 2001; Lang, Torre, & Weydert, 2002; McGeachie & Doyle, 2002; Keppens & Shen, 2002; López, Núñez, Rodríguez, & Rubio, 2002)). Besides, a formal definition of the preferences provides the entity with some negotiation capacity when interacting with other entities (Kraus, 1997; Sandholm, 1998; Lomuscio,

Wooldridge, & Jennings, 2001). Let us remark that, in most cases, utility functions take a very simple form. For instance, they may indicate that an entity E is willing to exchange the item a by the items b and c. Our framework consists of a set of agents performing exchanges of goods. Let us remark that it is not necessary to reduce all the transactions to *money*. In fact, most cognitive transactions are not based on money. Thus, an exchange is made if the involved parties are *happy* with their new goods, where the goods can be either tangibles or intangibles.

Note that, as transactions do not require money, the framework allows a richer structure of exchanges. First, money could be considered as another good, so we do not lose anything. Second, suppose a very simple circular situation where for each $1 \leq i \leq r$, agent A_i owns the good a_i and desires the good $a_{(i \bmod r)+1}$ (see Figure 1). This multi-agent transaction can be easily performed within this framework. On the contrary, it would not be so easy to perform it if these items must be first *converted* into money. In fact, in case items are to be converted into money, the agent who desires the most expensive item would be unable to obtain it. So, the whole exchange will be deadlocked, even though all the agents would get happier performing it. Actually, it could be thought that agents would be able to exchange the items provided that the price of all the items is the same, but in that case we are not really using money: If all the items have the same price, any item can be used as currency unit, and what we obtain is a barter environment where money is not needed. Moreover, in case the goods to be interchanged were intangible, the reduction to money would be quite complex.

The formalization of our system requires the notions of utility function, fair exchange, and equilibrium, borrowed from Microeconomics (see (Mas-Colell, Whinston, & Green, 1995) for a very formal and rigorous presentation of microeconomic theory). Let us suppose a system with k agents where n different tangible products and l intangible assets can be exchanged. Each agent has as information a tuple (The notation Att will be explained in the next section. It represents the possible attributes of an intangible good) $((\overline{x},\overline{\alpha}),u)$, with the pair $(\overline{x},\overline{\alpha}) \in (\mathrm{IR}\times\mathrm{Att})^n\times\mathrm{Att}^l$ and $u:(\mathrm{IR}\times\mathrm{Att})^n\times\mathrm{Att}^l \rightarrow \mathrm{IR}_+$. The first two components of the tuple denote the amount of tangible and intangible resources, respectively, that the entity owns of each good. The third component is the utility function indicating the preferences of the entity with respect to the different goods. That is, $u((\overline{x},\overline{\alpha})) < u((\overline{y},\overline{\beta}))$ denotes that the basket $(\overline{y},\overline{\beta})$ is preferred to the basket $(\overline{x},\overline{\alpha})$.

For the sake of simplicity, in the following example we assume that we are only dealing with material goods. In that case, u(2,3) < u(3,1) means that it is preferred to own 3 units of the first product and 1 unit of the second one than to own 2 and 3 units, respectively, of the corresponding goods. A subset of agents will be willing to exchange resources if none of them decreases its utility and at least one of them improves. These exchanges are called fair. Formally, let us consider $A=\{i_1,\ldots,i_m\} \subseteq \{1,\ldots,m\}$ and the tuples $((\overline{x}_i,\overline{\alpha}_i),u_i)$ for any $i\in A$. Let us suppose that after the exchange we have that the information associated with the agents belonging to A is given by the tuples $((\overline{y}_i,\overline{\beta}_i),u_i)$. The exchange is fair if for any $i\in A$ we have $u_i((\overline{x}_i,\overline{\alpha}_i)) \leq u_i((\overline{y}_i,\overline{\beta}_i))$ and there exists $j\in A$ such that $u_j((\overline{x}_j,\overline{\alpha}_j)) < u_j((\overline{y}_j,\overline{\beta}_j))$. Let us remark that a necessary condition for an exchange is that no products are created/destroyed, that is, $\sum_{i\in A}\overline{x}_i = \sum_{i\in A}\overline{y}_i$. However, this is not the case when exchanging information between entities (the producer of the info does not forget it). Eventually, the system will reach a situation where no more exchanges can be performed. In other words, it is not possible to improve the situation of one agent without

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