Multi-agent Negotiation under Time Constraints on an Agent-based Marketplace for Personnel Acquisition

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Abstract. A model for multi-agent negotiation under time constraints on an agent-based marketplace for personnel acquisition is presented. In the situation under consideration agents have contradictory aims and multi-lateral negotiation is chosen as the most suitable form for agents' co-ordination. Negotiation issues and negotiation strategies are discussed first. Then the general case of multi-lateral negotiation with multiple negotiation issues is considered. Although the paper deals with the specific situation of an electronic marketplace for personnel acquisition, the proposed negotiation model can be used with appropriate modifications for other agent-based e-marketplaces where agents have contradictory aims and negotiation is required.

1. Introduction

Electronic commerce is known to have many advantages compared to the traditional way of doing business such as 24 hours availability, up-to-date information and lower cost. To provide these advantages a lot of new tools and technologies were introduced. One of these new tools is software agents technology. Software agents are being increasingly used in a wide range of electronic commerce [1], [2], [9]. For an overview of agent-based e-marketplaces and their classification we refer to [6].

In many applications multi-agent co-ordination in one or another form plays a critical role. If the agents have contradictory aims and no direct control over one another, the most suitable form of co-ordination is negotiation either bilateral or multi-lateral. The agents negotiate to make other agents undertake a particular course of action or to come to an agreement about some matters. The best known techniques used to model agents' negotiation are game theoretic models, heuristic approaches and argumentation-based approaches. For an overview of these and other approaches we refer to [5] and [7]. The most interesting models both from theoretical and practical points of view are those dealing with multi-issue negotiation. In [4] a model for multi-issue negotiation between two agents under time constraints in an incomplete information setting was presented.

In this paper, a model for the multi-lateral multi-issue negotiation in the specific situation of an e-marketplace for personnel acquisition is introduced. Agent technology is shown to be quite useful for an electronic job marketplace. Users of

such a marketplace are employers looking for persons with specific qualifications, and persons looking for positions appropriate for them according to several criteria. Users create their individual agents who then can act in an autonomous manner and proactively. Once initialized they may continuously search for new positions (employees' agents) or for new potential employees (employers' agents). Based on their ability to learn, agents can analyze the situation on the marketplace and behave accordingly. Finally, to achieve their objectives (in our case, to find an appropriate position or an appropriate employee) the agents can negotiate about the contract conditions.

The remainder of the paper is organized as follows. Section 2 presents negotiation issues, scoring functions and negotiation strategies. In section 3, a model for multi-lateral multi-issue negotiation is presented. Section 4 provides the conclusions.

2. Negotiation issues and negotiation strategies

In the paper, a model for multi-agent negotiation under time constraints on an agent-based marketplace for personnel acquisition is presented. Time constraints mean that all agents acting on the e-marketplace have deadlines for their activities. All negotiation strategies and negotiation protocols are heavily using the agents' deadlines. Therefore we say that the negotiations we consider are in fact negotiations under time constraints.

In the proposed model, the negotiation subject is characterized by four issues: salary per hour, extra pays, number of working hours per week, and the employment duration. Let $x^i = (x_s^i, x_e^i, x_h^i, x_d^i)$ be an offer received by an employee's agent at the time $t = t_i$, $i = 0,1,...,n$ (n is the number of negotiation steps), where x_s^i is the value of salary per hour, x_e^i is the value of extra pays, x_h^i is the number of working hours per week, and x_d^i is the duration of employment offered to the employee's agent by an employer's agent at the time $t = t_i$. Analogously, let $y^i = (y_s^i, y_e^i, y_h^i, y_d^i)$ denote an offer received by an employer's agent at the time $t = t_i$, $i = 0,1,...,n$.

Different values of negotiation issues are of different value for negotiating agents. The value of negotiation issues is modeled by scoring functions N_s, N_e, N_h, N_d (for an employee's agent) and G_s, G_e, G_h, G_d (for an employer's agent). The bigger the value of a scoring function for a certain value of an issue is, the more suitable is this value for a negotiating agent. In our model the values of the scoring functions are always from the interval $[0, 1]$. If the value of a scoring function is equal to 1 for some value of an issue then the satisfaction level of a corresponding agent with this value will be 100 percent. The form of the scoring functions will in general be determined by the user initializing an agent. The scoring functions

represent private information not known by and not given to other market participants. The only requirement for the scoring functions following from the definition of the negotiation issues is that the functions N_s and N_e are monotonously increasing functions whereas the functions G_s and G_e are monotonously decreasing ones. As to the functions N_h, N_d, G_h, and G_d, they all increase monotonously first up to a certain optimal value, then they remain constant for some interval and then they decrease monotonously. For illustration we use the scoring functions in figures 1-3.

The scoring function $N_s(x_s)$ representing the value of salary per hour for an employee's agent is shown in figure 1.

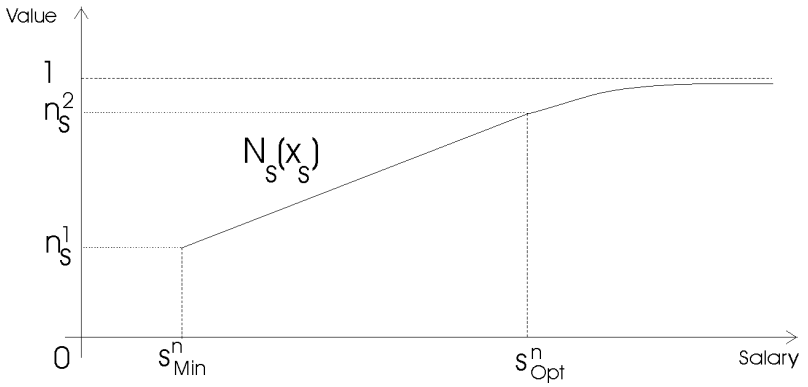


Fig. 1. Scoring function for salary used by an employee's agent

In figure 1, the values S^n_{Min} and S^n_{Opt} are the minimal salary per hour the employee would still accept and the highest expected salary per hour he/she is looking for, respectively.

The scoring function $G_s(y_s)$ of an employer's agent has the form presented in figure 2 (S^g_{Max} is the maximal salary the employer can pay to the employee, S^g_{Opt} is the salary the employer considers optimal for the given position).

The scoring functions $N_e(x_e)$ and $G_e(y_e)$ for extra pays look like the scoring functions $N_s(x_s)$ and $G_s(y_s)$.

The scoring function $N_h(x_h)$ for the number of working hours per week for an employee's agent is taken in the form presented in figure 3 (h^n_{Min}, h^n_{Max}, $h^n_{Opt_Min}$, $h^n_{Opt_Max}$ are the minimal, maximal and optimal numbers of working hours per week for the employee, respectively).

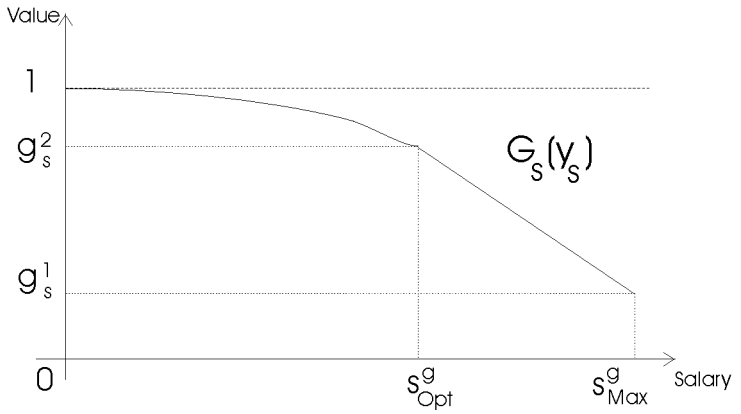


Fig. 2. Scoring function for salary used by an employer's agent

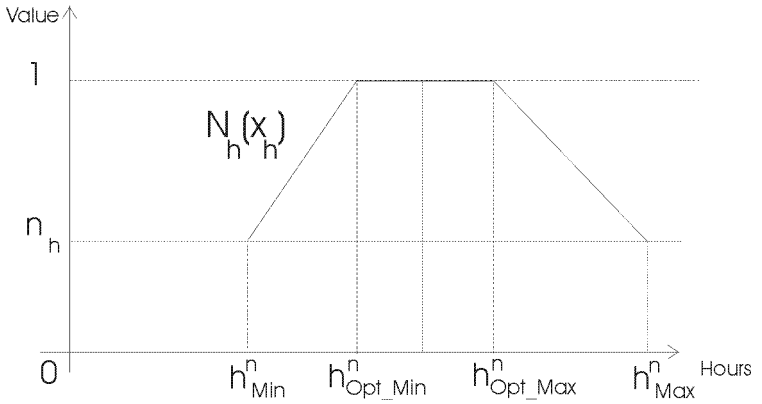


Fig. 3. Scoring function for the number of working hours per week used by employees' agents

The scoring function $G_e(y_e)$ for the number of working hours per week used by employers' agents and the scoring functions for the fourth negotiation issue, the employment duration, are modeled by functions of the same type as $N_h(x_h)$.

In a real negotiation, different negotiation issues are of different importance for each negotiation participant. To model this situation, the notion of relative importance that a participant assigns to each issue under negotiation is introduced. Let w_s^n, w_e^n, w_h^n, and w_d^n be the relative importance of salary per hour, extra pays, number of

working hours per week, and the employment duration, respectively, for an employee, and w_s^g, w_e^g, w_h^g, and w_d^g the relative importance of the same issues for an employer. For convenience, we assume that the normalization relations are valid:

$$w_s^n + w_e^n + w_h^n + w_d^n = 1, \quad w_s^g + w_e^g + w_h^g + w_d^g = 1. \tag{2.1}$$

Using the scoring functions and relative importance of issues under negotiation we can introduce the notion of a general scoring function. The exact form of this function depends on a specific situation. In our model, linear functions are used to construct the general scoring function for employees' and employers' agents:

$$N(x^i) = w_s^n N_s(x_s^i) + w_e^n N_e(x_e^i) + w_h^n N_h(x_h^i) + w_d^n N_d(x_d^i), \tag{2.2}$$

$$G(y^i) = w_s^g G_s(y_s^i) + w_e^g G_e(y_e^i) + w_h^g G_h(y_h^i) + w_d^g G_d(y_d^i). \tag{2.3}$$

Another question important for negotiation is how the agents generate their offers and counter-offers, i.e. negotiation strategies. In the case under consideration, agents' negotiations have multi-issue character, i.e., a negotiation strategy can be defined in general as a sequence of points in a multi-dimensional space.

By a negotiation strategy of an agent we mean a vector function $F(t, S_m, S_n)$ with four components:

$$F(t, S_m, S_n) = (f_s(t, S_m, S_n),\ f_e(t, S_m, S_n),\ f_h(t, S_m, S_n),\ f_d(t, S_m, S_n)),$$

where the functions $f_s(t, S_m, S_n)$, $f_e(t, S_m, S_n)$, $f_h(t, S_m, S_n)$, and $f_d(t, S_m, S_n)$ determine how the agent changes the values for salary, extra pays, number of working hours per week, and the employment duration, respectively, over the time depending on the status S_m of the e-marketplace and the status S_n of the negotiation. In general, S_m and S_n are multi-dimensional vectors containing components like number of agents present on the e-marketplace, number of agents participating in a negotiation, offers the agent receives, etc. The vector function $F(t, S_m, S_n)$ can be in general nonlinear and very complex. In fact, the question how to choose the appropriate form of the function depends heavily on the application where this agent-based negotiation is used. General recommendations regarding the form of such a function are not known; the only way to make an appropriate selection is by experimenting.

In the literature special cases of negotiation strategies are discussed [3], [8]. One important family of strategies consists of functions which are only time-dependent, i.e. neither the status of the marketplace nor the status of the negotiation influence the negotiation.

Other families of strategies which could be employed by the agents are resource-dependent and behavior-dependent strategies.

A resource-dependent strategy takes into consideration the number of offers and counter-offers the agents send to and receive from other agents, the number of agents acting on the e-marketplace and the number of agents who are potential partners for negotiation for a given agent. The general idea behind resource-dependent strategies is that the more potential agreements can be reached on the e-marketplace by an agent the slower can this agent change his values for negotiation issues and vice versa.

Taking a behavior-dependent strategy an agent has to analyze the behavior of other agents involved into the negotiation and generate his counter-offers according to the dynamics of how the values are changed in the offers he received.

In general, a strategy of an agent can be very complex, switching over time between time-dependent, resource-dependent, behavior-dependent, and other strategies.

3. Multi-lateral negotiation protocol

In this section the model for multi-lateral negotiations is discussed. In fact, multi-lateral negotiation over many issues takes place in many real life situations. On the electronic marketplace for personnel acquisition underlying this paper the nature of negotiation is multi-lateral. In general there are several potential employees who are interested in a position offered by an employer. Vice versa, several employers may be interested in a certain employee.

For multi-lateral negotiations we propose a negotiation protocol based on the bilateral protocol described in [3] (see also [4] for an extended version of this protocol) and a partial order of the set of all employees' agents generated by a pre-selection procedure.

3.1. Pre-selection procedure and partial order of the set of all employees' agents

Pre-selection means selecting those agents available on the marketplace that will negotiate in a specific process over certain issues. In the pre-selection process some additional factors like profession, age, working experience, professional and additional skills of the employees are taken into consideration. The values of these factors are fixed for the employees' agents and cannot be involved directly in the negotiation process although they are very important for the employment process.

For each employer's agent present on the e-marketplace all employees' agents which can be considered as potential partners for negotiation (i.e. the professions of the potential employees are the same the employer is looking for) are evaluated and ranked according to the values of the issues age, working experience, professional and additional skills. Thus a partial order of the set of all employees' agents is introduced for each employer's agent, meaning that all employees' agents are ordered according to the level they suit for negotiation with a given employer's agent.

To be able to rank the employees' agents, additional scoring functions have to be introduced for the employers' agents. The scoring function $G_a(y_a)$ for an employee's age is of the form presented in figure 3, i.e. in the process of the agent's initialization the employer has to input the values for minimum, maximum und optimal ages of the employee. As to the scoring function $G_{ex}(y_{ex})$ for the employee's working experience, this function is taken in the form of figure 1, where the points on the x-axis represent the minimal and the preferred working experiences of the employees.

The scoring functions both for professional skills (like knowledge of Unix, SQL, ASP or SAP R/3 etc.) and additional skills (like foreign languages, driving license, flexibility etc.) are discrete scoring functions, not continuous ones, because the functions have to be defined on the finite sets of all subsets of the finite sets of professional and additional skills. In our model, linear functions are used to model the discrete scoring functions, like

$$G_{ps}(y_{ps}) = a_1 \frac{b_1 b_r + b_2 g_r + b_3 e_r}{r} + a_2 \frac{c_1 b_d + c_2 g_d + c_3 e_d}{d}, \qquad (3.1)$$

where a_1, a_2, b_1, b_2, b_3, c_1, c_2, and c_3 are some constants such that $a_1 + a_2 = 1$, $b_1 + b_2 + b_3 = 1$, $c_1 + c_2 + c_3 = 1$, r is the number of required professional skills, d is the number of desirable professional skills, b_r is the number of professional skills the employee possesses with basic level out of r skills categories which are required by the employer, g_r and e_r are the numbers of professional skills with good and excellent levels, respectively, b_d, g_d and e_d are the numbers of professional skills with basic, good and excellent levels, respectively, an employee's agent possesses out of d skills categories which are desirable for the employer.

The scoring function $G_{as}(y_{as})$ for the employee's additional skills is constructed in analogy to the scoring function for the employee's professional skills.

Having constructed the scoring functions $G_a(y_a)$, $G_{ex}(y_{ex})$, $G_{ps}(y_{ps})$, and $G_{as}(y_{as})$ an extended set (w_s^g, w_e^g, w_h^g, w_d^g, w_a^g, w_{ex}^g, w_{ps}^g, w_{as}^g) of relative importance of negotiation and pre-selection issues is defined for an employer's agent: In addition to w_s^g, w_e^g, w_h^g, and w_d^g which were introduced before this set contains the relative importance of the employee's age w_a^g, working experience w_{ex}^g, professional skills w_{ps}^g and additional skills w_{as}^g. For convenience, the normalization relation is assumed to be valid:

$$w_s^g + w_e^g + w_h^g + w_d^g + w_a^g + w_{ex}^g + w_{ps}^g + w_{as}^g = 1. \quad (3.2)$$

For evaluation of an offer $y^i = (y_s^i, y_e^i, y_h^i, y_d^i)$ that is received from an employee's agent y the extended scoring function is used:

$$G_{ext}(y^i, y_{fix}) = G(y^i) + G_{fix}(y_{fix}), \quad (3.3)$$

where $G(y^i)$ is the scoring function (2.3) and

$$G_{fix}(y_{fix}) = w_a^g G_a(y_a) + w_{ex}^g G_{ex}(y_{ex}) + w_{ps}^g G_{ps}(y_{ps}) + w_{as}^g G_{as}(y_{as}), \quad (3.4)$$

$$y_{fix} = (y_a, y_{ex}, y_{ps}, y_{as}). \quad (3.5)$$

The extended scoring function (3.3) consists of two components. The first one, $G(y^i)$, is used to evaluate the received offers. The second one, $G_{fix}(y_{fix})$, reflects the fixed pre-selection issues like age, working experience, and professional and additional skills.

For a given employer's agent a partial order of the set of all employees' agents is introduced according to the following two rules:

1) The partial order is introduced only for those employees' agents who are potentially suitable for negotiation, i.e. the professions of the employees are the same as the profession the employer is looking for.
2) An employee's agent y is more preferable for the employer's agent than another employee's agent, say z, if and only if $G_{fix}(y_{fix}) \geq G_{fix}(z_{fix})$, where the functions and their arguments are defined as in formulae (3.4), (3.5). In this case, the relation between the two employees' agents is denoted by $y \ \phi \ z$.

Taking a particular employer's agent, a sequence $n_1, n_2, n_3, \ldots, n_l$ of the employees' agents is determined. This sequence is sorted according to the levels those agents are suited for the negotiation with the employer's agent:

$$n_1 \ \phi \ n_2 \ \phi \ n_3 \ \phi \ \ldots \phi \ n_l. \quad (3.6)$$

3.2. Multi-lateral negotiation protocol

The multi-lateral negotiation protocol presented in this sub-section uses heavily the bilateral negotiation protocol described in [3]. To save space the bilateral negotiation protocol is not specified in detail in this paper. Instead a short discussion of the idea of the bilateral protocol is presented.

The general idea behind the approach proposed in [3] is that two agents participating in the negotiation sequentially send each other offers and/or counter-offers. To generate the offers/counter-offers the negotiation strategies mentioned in section 2 are used. The interpretation of the offers (i.e. either to accept or to reject the offer/counter-offer) received from the other agent is based on scoring functions like (2.2), (2.3) constructed according to the agents preferences, restrictions, goals and relative importance of negotiation issues. The negotiation is completed either if an offer/counter-offer is accepted by one of the agents (negotiation is successful) or if one of the agents approaches his deadline (negotiation fails). For a formal presentation of the protocol for bilateral negotiation see [3].

Now a protocol for multi-lateral negotiations is introduced. A multi-lateral negotiation is modeled as a finite set of bilateral negotiations between one employer's agent and several employees' agents n_1 , n_2 , n_3 ,..., n_l satisfying the relation (3.6). However these bilateral negotiations are not independent, they are influenced by other bilateral negotiations. The negotiation of the employer's agent with any employee's agent is performed according to the bilateral negotiation protocol described in [3].

First the protocol for an employer's agent is presented. Suppose that t_{Max}^{g} is the deadline of the employee's agent and n_1, n_2 , n_3 ,..., n_l is the sequence of the employees' agents suitable for negotiation with the employer's agent satisfying the condition $n_1 \; \phi \; n_2 \; \phi \; n_3 \; \phi \; \ldots \phi \; n_l$.

1. At time $t = t_0$ start the negotiation with the employees' agents n_1 ,..., n_{l_1} , $l_1 \le l$ satisfying the condition

$$G_{fix}(n_1) = G_{fix}(n_k), \; k = 1,...,l_1$$

according to the bilateral negotiation protocol. In the case the employer's agent accepts an offer from one of the employees' agents he stops the negotiation with the agents n_1 ,..., n_{l_1} , $l_1 \le l$ and informs these agents by a special message about cancellation of the negotiation process.

2. Let l_m, $l_m < l$ be the index of the employee's agent last involved into the negotiation with the employer's agent. At time $t = t_i$, $i = 1,...,n$ start the negotiation according to the bilateral protocol with all the employees' agents satisfying the condition

$$G(x^i) + G_{fix}(n_{l_m}) \le G(x^0) + G_{fix}(n_k),$$

where x^i is the offer the employer's agent generates according to his strategy at time $t = t_i$, and the functions G and G_{fix} are defined as in the formula (3.3). In the case the employer's agent accepts an offer from one of the employees' agents he stops negotiating with all other agents and informs those agents by a special message that the negotiation process is cancelled.

3. If a message about cancellation of the negotiation process is received from one of the employees' agents, withdraw that agent from the set n_1, n_2, n_3,..., n_l of employees' agents participating in the negotiation.
4. At time $t = t_n$, $t_n \geq t^g_{Max}$ stop the negotiation with all the employees' agents involved in the negotiation and inform these agents by a special message about cancellation of the negotiation process.

Because the employees' agents play a more passive role in our model for multi-lateral negotiation than the employers' agents do, the protocol used by an employee's agent looks simpler than the protocol presented above. Let t^n_{Max} be the deadline of the employee's agent and g_1, g_2, g_3,..., g_k the sequence of the employer's agents currently involved in the negotiation with the employee's agent. Then the formal protocol for negotiation used by the employee's agent has the following form:

1. Negotiate with all the employers' agents g_1, g_2, g_3,..., g_k according to the protocol for bilateral negotiation. When the employee's agent accepts an offer from one of the employers' agents he stops the negotiation with the agents g_1, g_2, g_3,..., g_k and informs those agents by a special message about cancellation of the negotiation process.
2. If an offer is received from one of the employers' agents add that agent to the set of the employers' agents involved in the negotiation with the employee's agent.
3. If a message about cancellation of the negotiation process is received from one of the employers' agents involved in the negotiation, withdraw that agent from the set of the employers' agents participating in the negotiation.
4. At time $t = t_n$, $t_n \geq t^n_{Max}$ stop the negotiation with all the employers' agents involved in the negotiation and inform those agents by a special message about cancellation of the negotiation process.

According to our protocol, both employees' agents and employers' agents always send offers they themselves are satisfied with. Therefore, as soon as an offer is accepted by

one of the agents, the agent who sent the offer and the agent who received the offer come to an agreement at the same time.

3.3. An example of multi-lateral negotiation

To illustrate the protocol for multi-lateral negotiation an example of a multi-lateral negotiation from the employer's agent point of view is given in table 1.

In the example, one employer's agent negotiates with four employee's agents, say n_1, n_2, n_3, n_4. The agents satisfy the condition $n_1 = n_2 \phi n_3 \phi n_4$. Because the first two employee's agents are equally good according to criteria like age, working experience, professional and additional skills, the employer's agent starts to negotiate with those two agents. According to the bilateral protocol he sends them an initial offer x^0. As time passes, the values for the issues under negotiation in the offer of the employer's agents become smaller. Therefore at a certain stage the employer's agents can start a negotiation with the agent n_3 sending him the initial offer x^0. At the time $t = t_7$ the employer's agent receives the offer y_2^7 from the employee's agent n_2 which fits his preferences. The agent accepts that offer, informs the agents n_1, n_3, n_4 (some of them might be involved in negotiations with other employer's agents) about the cancellation of the negotiation process, and closes the negotiation.

Time	Offer sent to the employee's agent	Offer received from the employee's agent	Employee's agent	Condition
$t = t_0$	x^0		n_1	
	x^0		n_2	$G_{fix}(n_1) = G_{fix}(n_2) > G_{fix}(n_3)$
$t = t_1$		y_1^1	n_1	
		y_2^1	n_2	
$t = t_2$	x^2		n_1	
	x^2		n_2	$G(x^2) + G_{fix}(n_2) > G(x^0) + G_{fix}(n_3)$
$t = t_3$		y_1^3	n_1	

		y_2^3	n_2	
$t=t_4$	x^4		n_1	
	x^4		n_2	
	x^0		n_3	$G(x^4)+G_{fix}(n_2) \le G(x^0)$ $+G_{fix}(n_3)$
$t=t_5$		y_1^5	n_1	
		y_2^5	n_2	
		y_4^1	n_3	
$t=t_6$	x^6		n_1	
	x^6		n_2	
	x^2		n_3	$G(x^2)+G_{fix}(n_3)>G(x^0)+$ $G_{fix}(n_4)$
$t=t_7$		y_1^7	n_1	
	Offer accepted	y_2^7	n_2	
		y_4^3	n_3	

Table 1. Example of a multi-lateral negotiation (x^i is the offer the employer's agent generates in negotiation step i, y_j^i is the offer the employee's agent n_j generates in step i)

4. Conclusions

A model for multi-lateral negotiations under time constraints in the framework of an electronic agent-based marketplace for personnel acquisition was presented in this paper. For the special situation under consideration negotiation issues and negotiation strategies were constructed first. Using the bilateral model and the partial order of the set of all employees' agents created by the pre-selection procedure, the case of multi-lateral multi-issue negotiation was discussed.

The main idea behind the model is that not only issues under negotiation (like salary per hour, extra pays, number of working hours per week, and duration of employment) but also some other issues not directly involved in the negotiation (like

age, working experience, professional and additional skills) are considered in the protocol for the multi-lateral negotiation. The model presented in the paper introduces for each employer's agent a partial order of the set of all employees' agents which are suitable for negotiation with the given employer's agent. This partial order is then used in the negotiation process.

Due to the natural asymmetry in the preferences of the employers' und employees' agents, the protocol for multi-lateral negotiation is an asymmetric one. This means that the protocol for negotiation used by the employers' agents differs from the one used by the employees' agents. In a situation where there is no asymmetry in the agents' preferences all agents can negotiate according to the protocol introduced for the employers' agents.

The theoretical model for multi-lateral negotiation presented here was employed in a project at the European University Viadrina in Frankfurt (Oder), Germany. In this project, a prototype of an agent-based job marketplace for users with fuzzy constraints called FuzzyMAN (Fuzzy Multi-Agent Negotiation) was implemented. It is available for the public at http://www.wiwi.euv-frankfurt-o.de/wi-www/agent.htm. It is fuzzy or vague constraints which makes it possible to truly negotiate, i.e. to accept or reject a proposal and make a counter-proposal based on a certain strategy. Users wishing to find a new job and users wishing to hire new employees can initialize agents in FuzzyMAN by specifying a profession, salary per hour, social benefits, number of working hours per week, the period of employment, professional and additional skills, age, professional experience, and a negotiation strategy.

Although this paper dealt with the specific situation of an electronic marketplace for personnel acquisition, the proposed negotiation model can be used with appropriate modifications in the framework of any agent-based e-marketplace where agents have contradictory aims and negotiation is required.

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