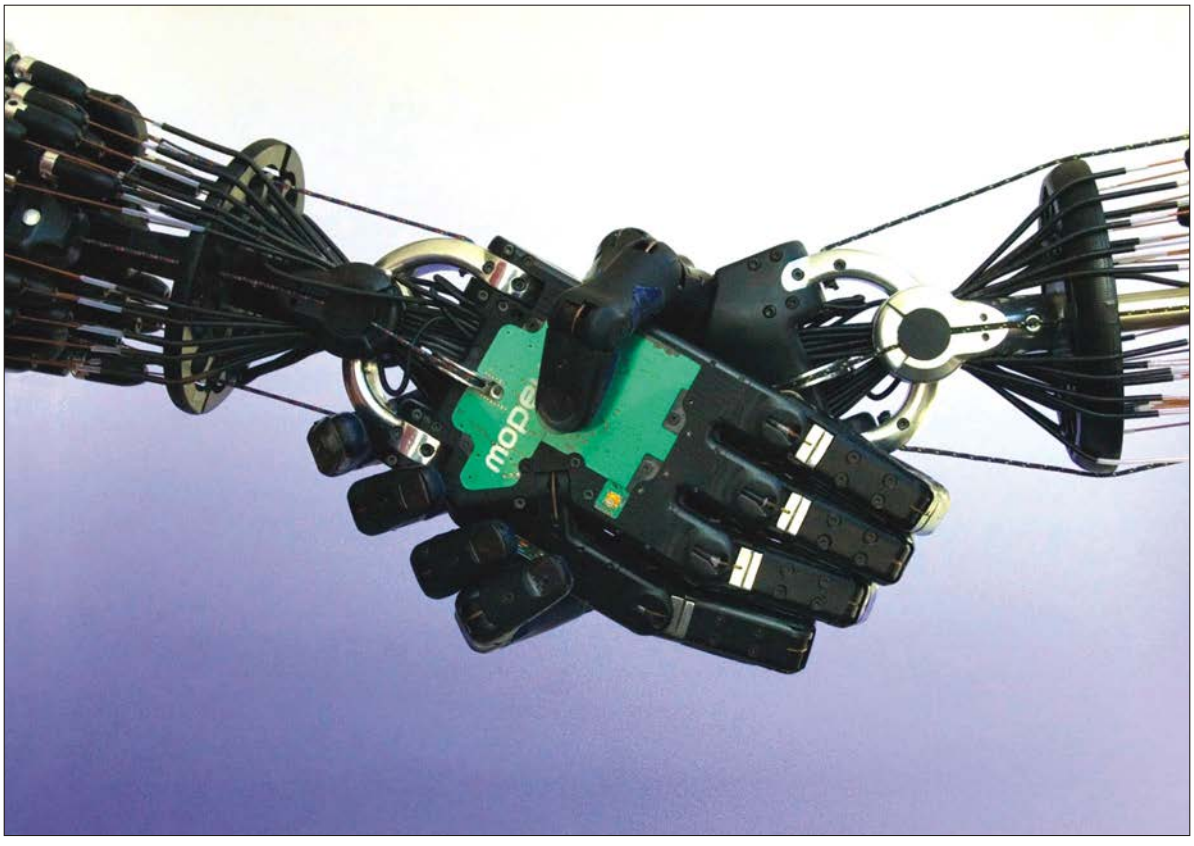

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Four-phased Process to Classify Negotiation Issues and Policies

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ABSTRACT

In this study a four-phased process towards classification of negotiation policies is being represented. In the first phase, negotiation methods are classified based on number of issues attending in the negotiation (one or many issues). In the second phase, relation of issues in multi-issue negotiations is being categorized as dependent or independent. By considering negotiation issues as independent ones, in the third phase, issues are being separated as common and peripheral issues. Finally, in the last phase, four negotiation policies according to kind of issues (common or peripheral) are being represented.

Key words: Software agents, multi-issue negotiation, independent issues, common issues, peripheral issues, negotiation policies

INTRODUCTION

Undoubtedly one of the most popular branches of research in inter-agent communication is dedicated to negotiation matter. In other words, in systems composed of multiple autonomous agents, the way of communication between these entities plays an important and significant role. The main way of communication in competitive multi-agent systems is negotiation (Fatima *et al*., 2005). Negotiation in multi-agent systems occurs around object/entities named issues. Issues are prominent factors that can affect negotiation process in some ways. Hence, in this study, firstly, negotiations are being divided into one-issue and multi-issue negotiation. Then, multi issue negotiation as the more popular form of negotiation is being classified as dependent and independent negotiations. By considering the fact that negotiating about dependent issues may have specific complexities, this study is being extended towards negotiating about independent issues. Hence in the third phase, independent issues are categorized as common and peripheral issues. Finally, in the last phase, negotiation policies and methods that are based on issues' kinds (common and peripheral) are being introduced.

Level one: One-issue and multi-issue negotiation and optimal agenda: The simplest form of negotiation involves two agents (for instance, seller agent and buyer agent in autonomous electronic commerce contexts) and a single-issue; For example consider sample scenario of seller and buyer who negotiate about price. To begin, two agents are likely to differ on the price at which they believe the trade should take place, but through a process of joint decision-making they either arrive at a price that is mutually acceptable or they fail to reach an agreement (Fatima *et al*., 2006).

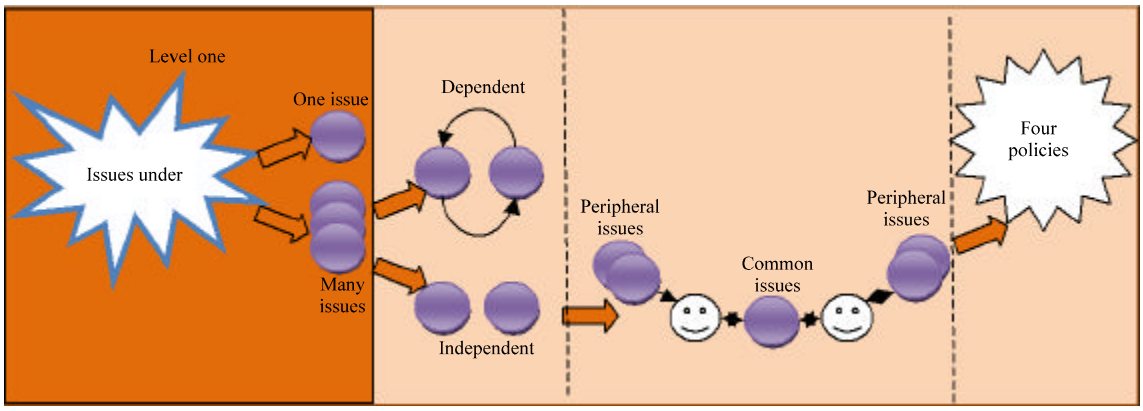

Fig. 1: Level One: one-issue and multi-issue negotiation

However, in most bilateral negotiations, the parties involved need to settle more than one issue However, in most bilateral negotiations, the parties involved need to settle more than one issue. (Fig. 1). For example, agents may need to come to agreements about objects/services that are characterized by issues such as price, delivery time, guarantee, quality, reliability, timings, penalties, terms and conditions and so on (Jennings *et al*., 2001). In recent years, there have been few researches in this new field which have led to the formation of two fundamental concepts as follows (Fatima *et al*., 2004; Wooldridge *et al*., 2004):

- **Negotiation procedure:** Which clarifies the issues to be negotiated as a package simultaneously, or separately and in different times
- **Agenda:** which identifies the set of issues under negotiation (we call it common agenda sometimes)

There is a common question among different researches on agenda which refers to defining the best candidates for each agent. In other words, it evaluates which candidate provides more utility for each agent and will be located in its optimal agenda? The answer helps agents to select the proper issues in a negotiation. Based on Wooldridge *et al*. (2004), for each issue in the agenda the participating agents in a negotiation may have or have not a zone of agreement.

- **Note:** In (Wooldridge *et al*., 2004), the optimal agendas for two negotiating agents α and $\acute{\alpha}$, in a situation where two issues A and B are candidate to be negotiated, are shown by $A^{\alpha}_{\circ}$ and $A^{\acute{\alpha}}_{\circ}$, respectively. Because of existence of two candidates issues for negotiation , four negotiation scenario are possible:

S_1: Both issues have a zone of agreement
S_2: Only issue A has a zone of agreement
S_3: Only issue B has a zone of agreement
S_4: Neither issue A nor issue B has a zone of agreement

It is clear that among these four scenarios, in scenario S_1 and S_4, agents' optimal agendas are the same and they consist of either issues or none of them. But, for two other agents in scenarios

S_2 and S_3 negotiating is useful only about one issue (A or B) for both sides and optimal agendas are different. Optimal agendas of two agents for two different cases in scenario S_2 are shown in Fig. 2 and 3 (Fig. 2 is related to part a and Fig. 3 is related to part b of this scenario). In these figures the utility boundaries for issues A and B are called AA' and BB' respectively and horizontal axis show agent α's utility and vertical axis shows agents 'A 's utility for these two issues).

- As it is clear in Fig. 2, issue B has positive utility for none of the agents (is placed in quadrant Q_3). Apparently, none of the agents accepts negotiating about B in this case and optimal agendas of two agents just consist of issue {A}
- Another case is that issue B has positive utility for one of the agents (is placed in quadrant Q_2 or Q_4). It is predictable that in this case, only the agent that receives positive utility from negotiating about B adds it to its optimal agenda. Therefore, the optimal agendas will be in one of these two forms:

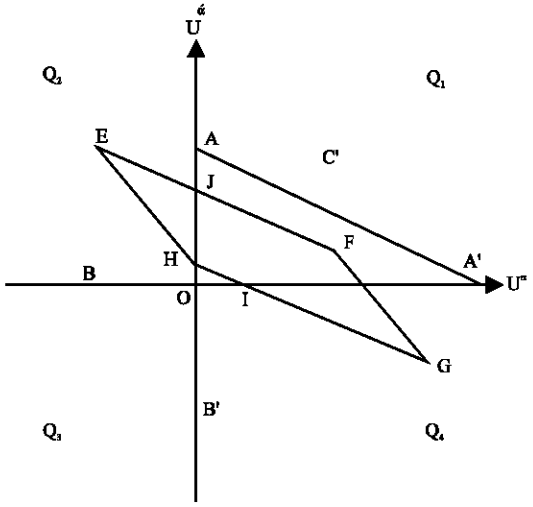

Fig. 2: Agents utilities in scenario S2 (Part a)

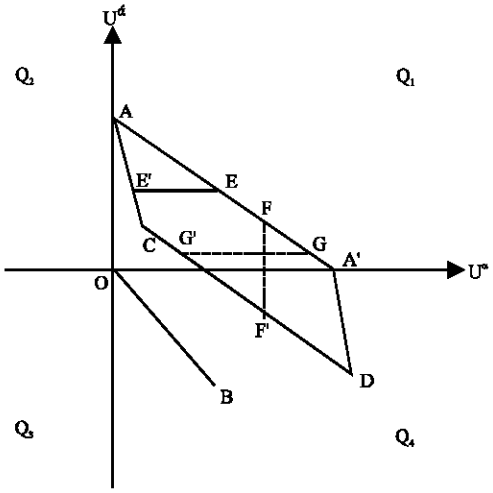

Fig. 3: Agents utilities in scenario S2 (Part b)

$$A^{\alpha}_{0} = \{A,B\}, A^{\bar{\alpha}}_{0} = \{A\}$$

$$A^{\alpha}_{0} = \{A\}, A^{\bar{\alpha}}_{0} = \{A,B\}$$

For example in Fig. 3, only agent α gains a positive utility from negotiating on issue B and the optimal agendas are:

$$A^{\alpha}_{0} = \{A,B\}, A^{\bar{\alpha}}_{0} = \{A\}$$

Level two: Dependent or independent issues: Four main scenarios for two issues (issues A and B) that are under negotiation were discussed in previous section. If these issues affect each other (are dependent), identification of negotiation's effective issues will be so hard for agents. For instance, in Fig. 3 the gained utility of agents from negotiating about issue B locates in the fourth quarter and negotiating about this issue brings a negative utility for agent $\bar{\alpha}$. Hence, by considering the issues as independent issues, issue B will not be located in $\bar{\alpha}$'s optimal agenda. While considering the issues as dependent issues, it is possible that negotiating about this issue results in agent $\bar{\alpha}$ to gain another privilege (from another dependent issue) that compensates this loss for it or totally gains a positive utility after negotiating about it. As a result, issue B may also enter the agent $\bar{\alpha}$ optimal agenda. Obviously, under this circumstances deciding whether issue B is totally effective for agent or not is so complicated (Fig. 4 shows classification of multi-issue negotiation to dependent and independent issues).

According to foregone, work to date on negotiation protocols has focused on negotiating what we can call 'simple' contracts, i.e. contracts consisting of one or a few independent issues (Klein *et al.*, 2003; Faratin *et al.*, 2003). These protocols work via the iterative exchange of proposals and counter-proposals. Since issues are independent, the utility of a contract for each agent can be calculated as the weighted sum of the utility for each issue. The utility function for each agent is thus a simple one, with a single optimum and a monotonic drop-off in utility as the contract diverges from that ideal. The simplicity of the utility functions makes it feasible for agents to infer enough about their opponents that they can identify concessions, resulting in relatively quick negotiations.

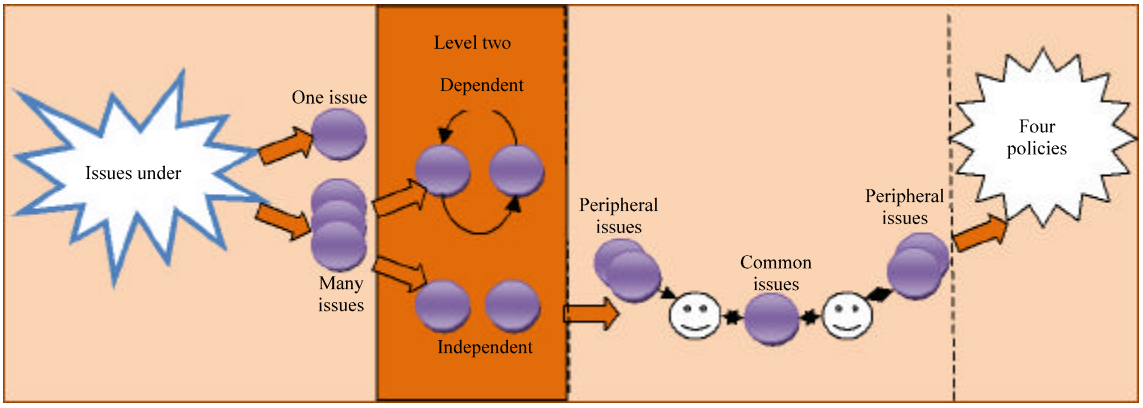

Fig. 4: Level Two: Dependent and Independent issues

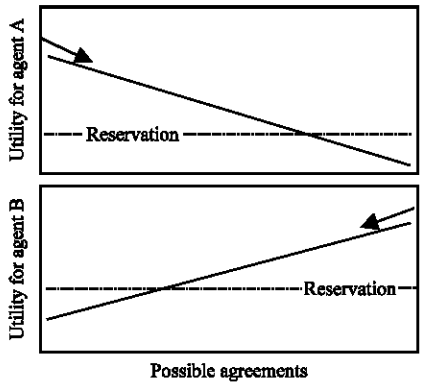

Fig. 5: The standard view of negotiation

What happens in such techniques can be analyzed using Fig. 5. Each point on the X axis represents a candidate design agreement. The Y axis represents the utility of each agreement to each agent, where higher is better.

In such a context, the reasonable strategy is for each agent to start at its own ideal design and concede, through iterative proposal exchange, just enough to get the other party to accept the agreement.

Real-world contracts, by contrast, are generally much more complex, consisting of a large number of inter-dependent issues (Faratin *et al*., 2003). Even with only 50 issues and two alternatives per issue, we encounter a search space of roughly 10^15 possible contracts, too large to be explored exhaustively. The value of one issue selection to an agent, moreover, will often depend on the selection made for another issue. Such issue interdependencies lead to nonlinear utility functions with multiple local optima.

In such a contexts, an agent finding its own ideal contract becomes a nonlinear optimization problem. Simply conceding toward the other agents' proposals can result in the agents missing contracts that would be superior from both their perspectives.

Standard negotiation techniques thus typically produce the behavior shown in Fig. 6 when applied to complex contract negotiation.

Based on the abovementioned information and existence of different complexities, in most researches issues have been considered independent and their probable effects on each other have been neglected.

Level three: Common and peripheral issues (Fig. 7): As mentioned and by considering their complexities, dependent issues usually are not being considered for negotiation. In this case, participating issues in the negotiation can be divided into two main groups: common issues and peripheral issues (Darooei and Khayyambashi, 2009a, b, 2010; Darooei *et al*., 2010).

In order to understand common and peripheral issues' differences, consider following sample (Darooei and Khayyambashi, 2009c):

Example: Imagine that valuable issues of buyer agent and seller agent are as follows:

Valuable issues of buyer = {price, quality}

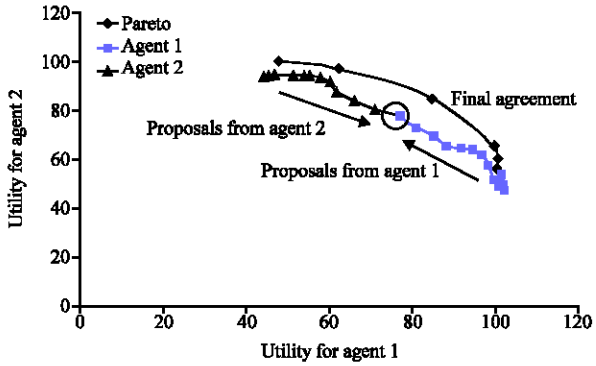

Fig. 6: The utilities for the proposals made in a typical complex

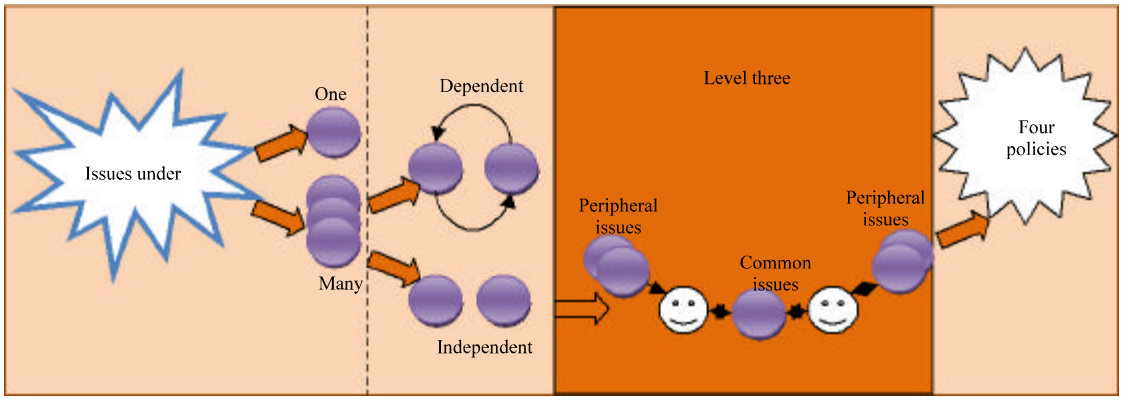

Fig. 7: Level three: common and peripheral issues

$$\text{Valuable issues of seller} = \{\text{price, timing}\}$$

- As it is clear, price is a common issue between two trading agents. This means both agents are interested to negotiate about this issue and therefore negotiating about it could be beneficial for both of them. As a result, this issue will be added to common set (com), which is the intersection of two above sets:

$$\text{Com} = \{\text{price}\}$$

- On the other hand, issues such as quality and timing are just beneficial for one of the agents and brings about utility loss for other agent (since if they were beneficial for other agent, that agent also entered that issue to its valuable set) and they will be added to peripheral set of buyer ($\text{Per}_{\text{buyer}}$) and peripheral set of seller ($\text{Per}_{\text{seller}}$), respectively.

$$\text{Per}_{\text{buyer}} = \{\text{quality}\}$$

$$\text{Per}_{\text{seller}} = \{\text{timing}\}$$

Level four: four possible negotiation policies: However, the main question is that how each agent will react while negotiating about its' opponent's peripheral issues (Darooei and Khayyambashi, 2009b). As illustrated in Fig. 8, in this situation four main policies can be applied: optimistic- pessimistic- realistic- extended realistic.

Optimistic policy: With an optimistic look to gain a maximum positive utility (this is the reason we call it optimistic policy), in this policy negotiation occurs around all the available issues and no condition will be checked. Hence, the fundamental advantage of applying this algorithm is simplicity and generality of its way of use. It also satisfies all agents' preferences, since it allows entrance of all the issues to the negotiation. However, there is a probability that reaching agreement about peripheral issues would not be possible or agents totally would face utility loss after negotiating about such issues (in other words, existence of peripheral issues results in the risk of utility loss to be equivalent with the chance of getting maximum positive utility). While as mentioned in advance, agents are self-interested creatures that never accept utility loss. As a result, optimistic policy will not be applicable practically. These facts are shown in Fig. 9 graphically.

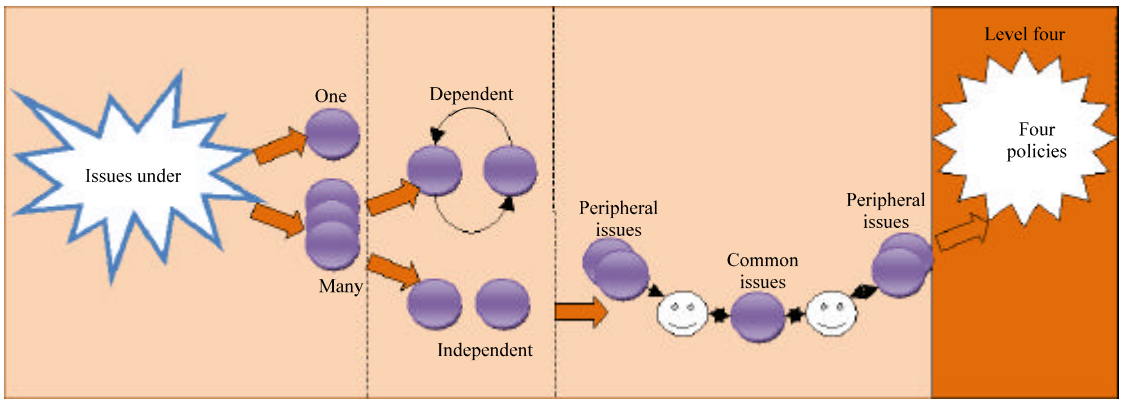

Fig. 8: Level Four: 4 possible negotiation policies

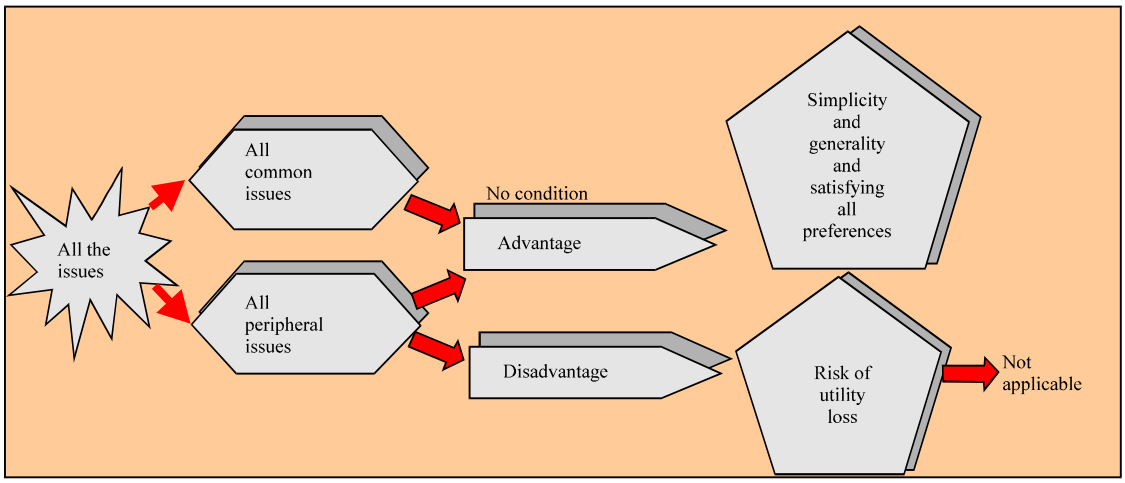

Fig. 9: Pros and cons of applying optimistic policy

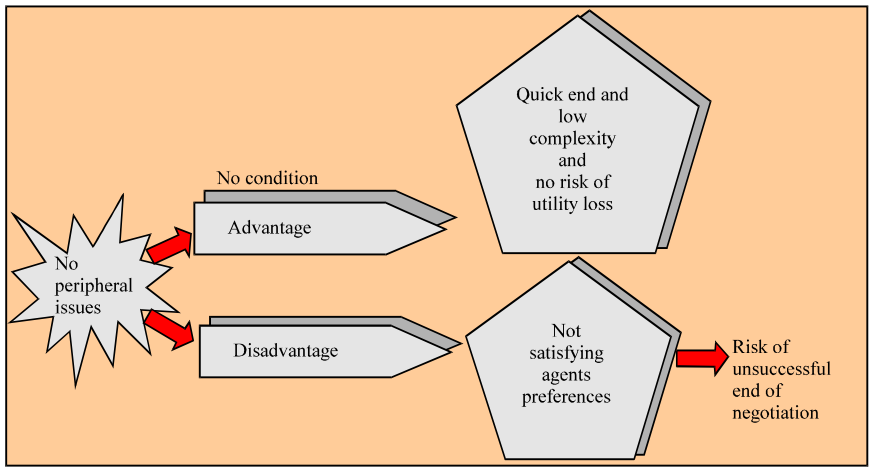

Fig. 10: Pros and cons of applying pessimistic policy

Pessimistic policy: In contrast with optimistic policy- to avoid the risk of utility loss- the second policy does not allow entrance of peripheral issues to the negotiation process. Therefore, only the issues that are beneficial for both sides of negotiation will enter this process. Obviously, the main challenge with this policy is its' pessimistic sight to peripheral issues which briefly avoids presence of these issues in the negotiation process. This matter brings about a considerable problem; not satisfying agents' preferences about negotiating around their peripheral issues. While, an agent may insist on satisfying specific preferences of its own and if not, it may ignore negotiating with related opponent. On the other hand, a great advantage of applying this policy is its faster trend which is the result of limiter number of issues that attend into negotiation process. In addition, its lower degree of complexity and no risk of utility loss (because no peripheral issues attend in the negotiation and no condition should be checked to avoid utility loss) are other advantages of this policy. These facts are shown in Fig. 10 graphically.

Realistic policy: According to this policy, for an agent, negotiation occurs just around the peripheral issues of opponent that the risk of negotiating about them can be compensated by positive utility of negotiating about its own beneficial peripheral issues.

As mentioned, the great challenge in the optimistic policy is risk of utility loss. Thus, the realistic policy which in fact is a mixture of two previous policies limits the peripheral issues of the negotiation to the issues that totally do not cause utility loss for neither of agents (in other words, the positive utility that each agent gains after negotiating about its own peripheral issues should be greater than negative utility of negotiating about opponent's peripheral issues).

This policy also solves the pessimistic policy's problem by providing the chance of presenting more peripheral issues in the negotiation. Hence, more preferences of agents about negotiating around their issues will be satisfied. Clearly, to avoid utility loss in this policy specific conditions should be checked. The condition is that the total gained utility of negotiating about both sides' peripheral issues should be a positive value (Fig. 11: P1+P2>0 – in this figure P1 and P2 are peripheral issues of two agents). As a conclusion, this policy has highest degree of complexity comparing to two previous policies. Additionally, if only one of the agents owns peripheral issues, this policy will not be applicable (since in this policy the total gained utility of both sides' peripheral issues are being computed). These facts are shown in Fig. 11 graphically.

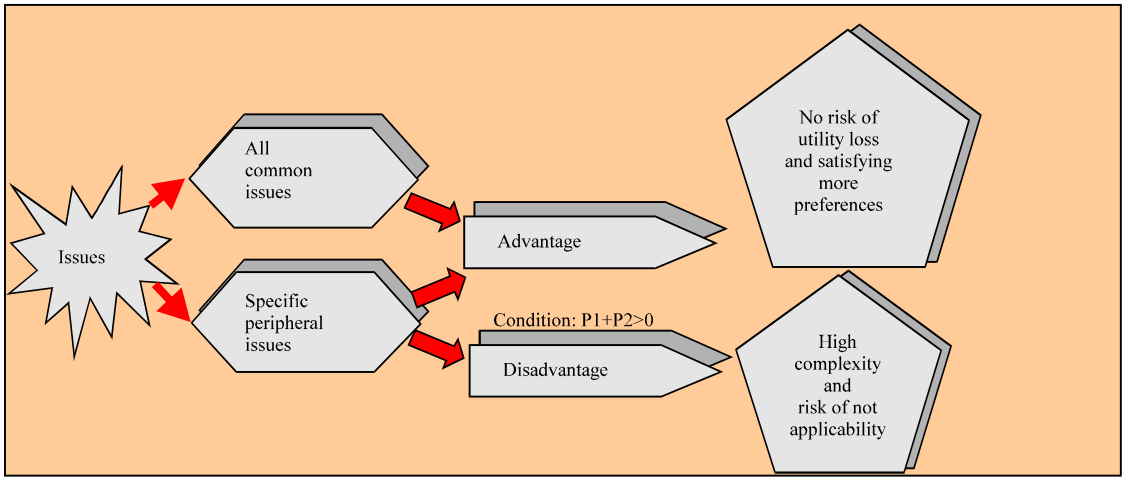

Fig. 11: Pros and cons of applying realistic policy

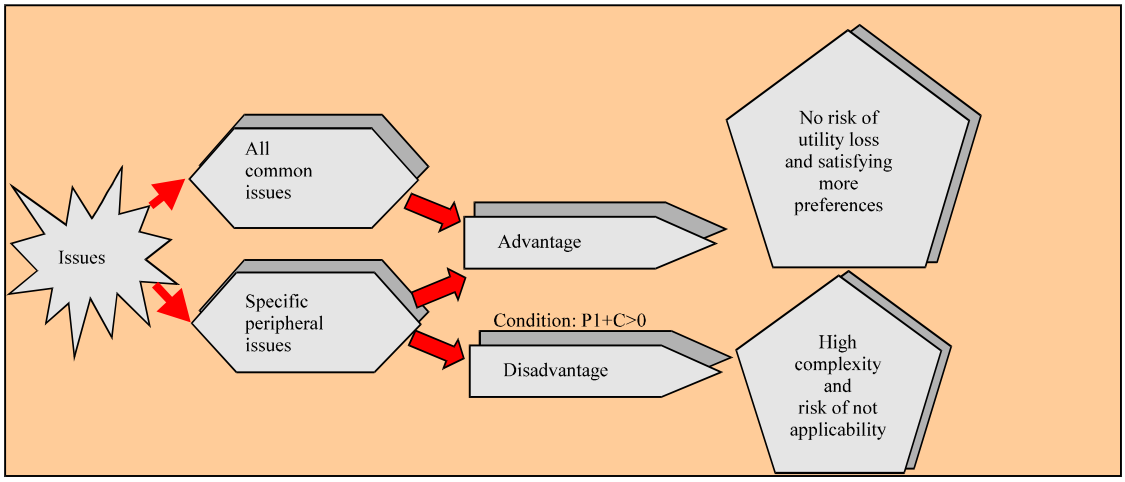

Fig. 12: Pros and cons of applying extended-realistic policy

Extended-realistic policy: As discussed, optimistic and pessimistic policies' problems were resolved by applying realistic policy. However, realistic problem also suffers from situation where just one of the agents own peripheral issue s (see explanation for realistic policy). Assuredly, under this circumstance applying optimistic policy also results in utility loss for one the agents (the agent that has no peripheral issue). As a conclusion, the only applicable policy to overcome this situation seems be pessimistic policy in which negotiating about peripheral issues is being neglected completely. However, applying pessimistic policy not only is restrictive, but also may cause unsuccessful end of negotiation (Fig. 10). Hence, another policy named extended-realistic may be applied in which (like realistic policy) negotiation occurs around only specific peripheral issues of an agent (Darooei and Khayyambashi, 2010). In contrast with realistic policy, these peripheral issues are those that the loss came from negotiating about them can be compensated by an increase in common issues' utilities for other agent (Fig. 12: P1+C>0– in this figure, C is the common issues utility). In other words, the agent that owns peripheral issues has to concede some part of its common issues' utility to the other agent to convince it to start negotiating about peripheral issues.

Obviously, this policy also suffers from complexity problem because of essence of checking some conditions. However, this policy is the only applicable method for situation where just one of the agents owns peripheral issues.

CONCLUSION

Multi-agent negotiation as one of the most interesting subjects of research is under vast attention and consideration these days. As a result, with the aim of comforting realization of negotiation notion, lots of classifications have been offered in this field. Some of these classifications classify negotiations based on number of issues attending in them (one- many). Some others classify negotiations based on interdependencies between issues (dependent-independent). Third group classifies them based on kinds of issues (whether they are beneficial for both sides or just for one side of negotiation). Finally the last group classifies them considering the policies which they are based on. Hence, in this review paper the invisible connection between these classifications has been illustrated using a four-phased diagram. This diagram shows how it is possible to reach the fourth classification using third one, to reach third classification using second one and reach second classification using first one.

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