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An Automated Negotiating Agent that Searches the Bids around Nash Bargaining Solution to Obtain High Joint Utilities

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The International Automated Negotiating Agents Competition (ANAC) and the Pacific Rim International Automated Negotiation Agents Competition (PRIANAC) are being held annually in order to bring together the researchers from the multi-agent automated negotiation community. In this paper, we present a negotiating agent that is capable of searching the suitable bids that obtain high joint utility values near Nash bargaining solution by using a novel bid searching strategy. The proposed agent has participated in both competitions and finished in second place in the social welfare category in ANAC 2018 and in first place in the social welfare category in PRIANAC 2018.

1. Introduction

In this paper, we present a novel bid searching strategy that is proposed for an automated negotiating agent in order to participate in ANAC Repeated Multilateral Negotiation League (RMNL) 2018 and PRIANAC 2018[1]. As a competitive challenge in ANAC 2018 [2], RMNL requires the participants to design and implement an automated negotiating agent, that is able to negotiate with two opponent agents and is capable of learning from its previous negotiation experiences. The same challenge in PRIANAC 2018 requires the design of the same type of automated agent that is able to negotiate only with one opponent agent. In addition, this challenge permits the usage of a local file in order to save the bids that were offered by the opponent agent, and a machine learning library. In order to address this challenge, we propose a novel negotiation strategy that is capable of finding the preference issues and values of each agent, then combining those issues and values in order to generate the bids that provide high joint utility values near Nash bargaining solution.

2. Negotiation Environment

2.1 Negotiation Competition

RMNL in ANAC 2018 is a repeated multi-party closed negotiation competition among three agents. RMNL assumes no previous knowledge of the preferences and strategies of the opponent agents, wherein the negotiating agents use the Stacked Alternating Offers Protocol (SAOP)[3]. In this context, each agent is given three minutes to deliberate. Each negotiation round is repeated five times. Also, the utility functions are linear and the participant agents are able to negotiate about a large set of previously unknown preferences. Similarly, PRIANAC 2018 is a bilateral negotiation competition. In this context, PRIANAC 2018 competition assumes no previous knowledge of the preferences of the opponent agents, wherein the negotiating agents use the Alternative Offer Protocol (AOP)[3]. Each negotiation round has ten seconds and the number of negotiation rounds on the same configuration is set to 100. Both competitions use GENIUS[4] platform.

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2.2 Preferences of the Negotiating Agents

The preferences for each agent in all negotiation domains are represented by a weighted sum utility function. In this regard, each agent has its own utility function. This utility function is expressed as follows:

$$u_a(b^t) = \sum_{j \in I} V_a(b_j^t) \cdot w_{a,j} \quad (1)$$

According to Equation (1), each negotiation issue $j \in I$ can take a value v_j from a predefined set of valid values for that issue which is denoted by D_j (i.e., $v_j \in D_j$), where each agent can access this domain information. In addition, a bid $b = (b_1,...,b_{|I|})$ is an assignment of values to all issues where $b_1 \in D_1$. $V_a(v_j)$ denotes Agent a valuation of the value of issue j.

3. Proposed Approach

3.1 Bid Searching Strategy

The proposed bid searching strategy aims to find the bids around Nash bargaining solution because these bids are expected to possess higher values of the joint utility function. In order to achieve this goal, the proposed method aims to find the priority issues for each opponent agent after analyzing the series of bids offered by this agent.

The main idea is dividing these bids into negotiation issue units, selecting the priority issue and value for each opponent agent and then generating new bids which not only have high utilities, but also include those prior issues and values. Therefore, the bid searching space becomes unrestricted to the already offered bids, instead, the new bids which include all the preference issues from different agents are expected. In addition, in PRIANAC 2018, we save and analyze all the bids that are offered by the opponent agents, in all negotiation rounds of the same negotiation domain, to

a local file. With the increasing number of bids, the accuracy of determining the preference for the opponent agent also increases. This bid searching strategy that is used in both ANAC 2018 and PRIANAC 2018 includes five steps.

The bid searching strategy is represented by Algorithm 1 as follows:

Algorithm 1 Bid Searching Strategy

Issues: given by a scenario, such as: ***a, b, c, d, e.***
Values: given for each issue by a scenario, such as: ***a1, a2, a3, a4, a5*** *for issue* ***a.***
for all *opponent participant agents* **do**
  for all *issues:* ***a, b, c, d, e*** **do**
    calculate the average of all the values in all offered bids
    calculate the standard deviation of all the values (VSD)
  end for
  calculate the standard deviation of all the issues' VSD (ISD)
  if $ISD > 0.0$ **then**
    The agent has preference
    Compare the preference of issues
    Choose the prior issue and the prior value
  else
    Choose the prior issue and the prior value randomly
  end if
end for
while true **do**
  generate the bid with the prior issues and values of opponent participant agents
  if *the utility of the generated bid ¿ threshold* **then**
    offer the bid
  end if
end while
if *the offered bid is accepted by all opponent agents* **then**
  negotiation succeeds
  save the list of offered bids to a local file
else
  update offered bids list and go to step 3
end if

In addition, a sample demonstration is shown in Figure 1 according to the following steps. First, calculate the standard deviation of each value in each issue, which is denoted as value standard deviation. Second, calculate the standard deviation of value standard deviation of each issue, which is denoted as issue standard deviation. Third, set issues with high value standard deviation as prior issues, and values with high frequency as prior values. Fourth, search the utility of the bids with prior issues and prior values, randomly. If the utilities of these bids are higher than a predefined threshold value, make an offer. Fifth, if the negotiation succeeds, save the list of offered bids to a local file. Otherwise, update the list of offered bids and return to the first step.

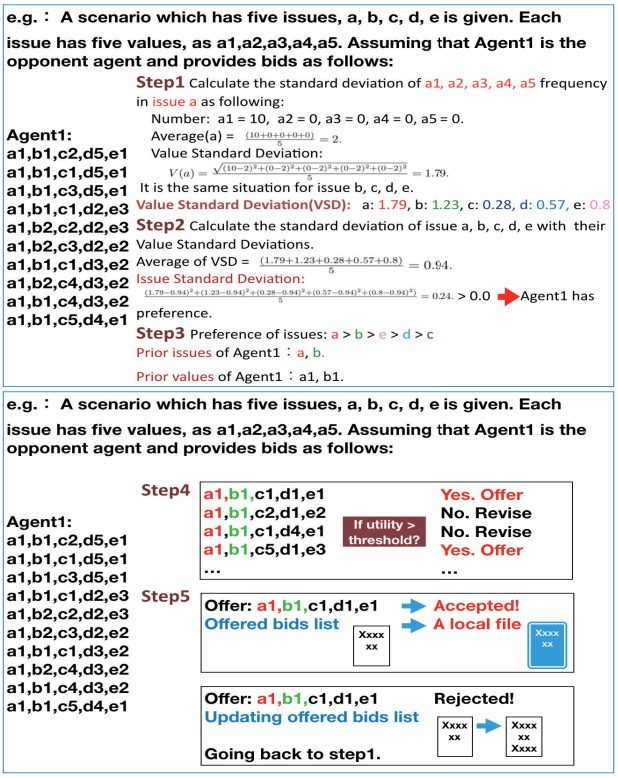

Figure 1: An example of bid reconstruction method

3.2 Bid Acceptance Strategy

A compromise function is used in order to judge whether or not to accept an offered bid. If the utility of a certain bid is greater than a preset threshold value, then the proposed agent accepts this bid. This threshold value decreases as time passes. In this context, this threshold value is calculated using the following equation.

$$Threshold = \max\{(1-(1-df)\cdot\log(e-1.9+(e-1)^{\alpha})\cdot t), emax\} \quad (2)$$

In this equation, df represents a discount factor. α is a parameter which we set as 4.5. t represents the current time. $emax$ represents the estimated maximum utility which is calculated using the following equation.

$$emax(t) = \mu(t) + (1 - \mu(t)) \cdot d(t) \quad (3)$$

Where, $\mu(t)$ is the mean utility of the opponent offers in the utility space of a certain agent. $d(t)$ [5] is a function for estimating the utility width of the opponent offers in the utility space of this agent. This utility width is given by Farma Agent in the ANAC 2016 competition as follow:

$$d(t) = \frac{\sqrt{3}\sigma(t)}{\sqrt{\mu(t)(1-\mu(t))}} \quad (4)$$

Where, σ is the standard deviation.

4. Results and Evaluation

Both competitions, i.e., ANAC 2018 and PRIANAC 2018 have two categories: the individual category, in which the

participant agents are ranked according to the individual utility they have obtained; and the social welfare category in which the participant agents are ranked by their social utility. This social utility is the sum of the individual utilities of all agents. The proposed agent won the second place in the final round of the social welfare category in ANAC 2018 and also won the first place of the social welfare category in PRIANAC 2018. These results demonstrate the efficiency of the proposed agent and its ability to find high joint utility solutions.

ANAC 2018 The final round has been run among nine finalists in each category with four selected scenarios submitted by the participants. For each scenario, 2520 negotiations were run. The results of the qualifying round and the final round of the social welfare category are presented in Figure 2.

Qualify Round Result (Pool C)

Agent Name	Individual Utility	Social Welfare
AgentNP1	0.512177707	1.52976242
GroupY	0.485323479	1.33874982
ATeamAgent	0.345297603	0.980979189
Sontag	0.484535782	1.515047114
Agent33	0.428666974	1.419233621
Agent_Hama	0.469592183	1.393009022
Exp-Rubick	-	-

Figure 2: Qualify Round Result in ANAC 2018

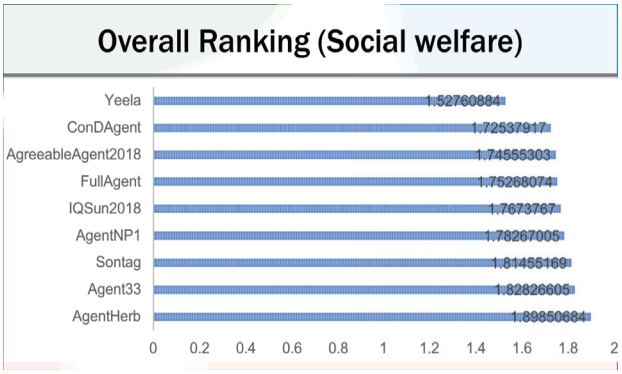

Figure 3: Results in ANAC 2018

PRIANAC 2018 The competition has been held among 6 agents with 120 negotiation scenarios which are generated by the organizers. In each tournament, 12,000 sessions were run. The results of the social welfare category are presented in Figure 3.

5. Conclusion and Future Work

This paper proposes a negotiating agent that implements a novel bid reconstruction method in order to search the suitable bids that obtain high joint utility values. Towards this end, the bid reconstruction method utilizes the previously offered bids by the opponent agents in order to construct the successful bids around Nash bargaining solution. The final round results of ANAC RMNL 2018 competition and the results of PRIANAC 2018 competition demonstrate that the proposed agent is able to search the scope of suitable bids around Nash bargaining solution and succeeds to lead other participant agents where the negotiating agent achieves higher values of joint utilities. Future work is set to study the necessary improvements that are needed to achieve a high individual utility value and to investigate the usage of machine learning to help reduce the scope of bid searching.

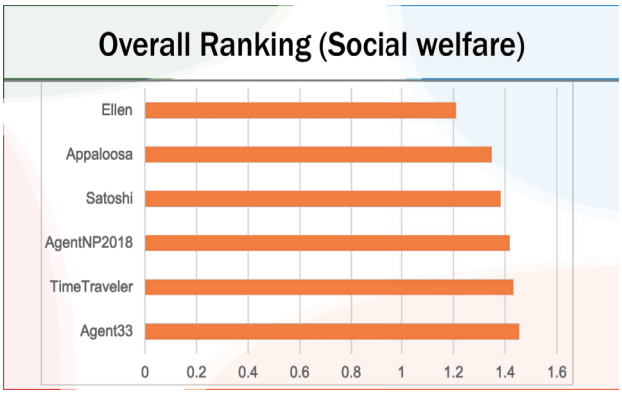

Figure 4: Overall Ranking (Social Welfare) in PRIANAC 2018

References

[1] PRIANAC 2018 (Pacific Rim International Automated Negotiation Agents Competition), http://web.tuat.ac.jp/ katfuji/PRIANAC2018/.

[2] ANAC 2018 (Ninth International Automated Negotiating Agents Competition), http://web.tuat.ac.jp/katfuji/ANAC2018/.

[3] Aydoğan, R., Festen, D., Hindriks, K. V., & Jonker, C. M. (2017). Alternating offers protocols for multilateral negotiation. In Modern Approaches to Agent-based Complex Automated Negotiation (pp. 153-167). Springer, Cham.

[4] Lin, R., Kraus, S., Baarslag, T., Tykhonov, D., Hindriks, K., & Jonker, C. M. (2014). Genius: An integrated environment for supporting the design of generic automated negotiators. Computational Intelligence, 30(1), 48-70.

[5] Toyama T., Takayuki, I. (2016). Concession based on Maximum Utilities Estimated by a Divided Uniform Distribution.