Gentle

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1 Negotiation Management

Gentle inherits *AdaptiveAgent* and negotiates with opponents independently. Negotiation choices are the same way of the inheritance class, and Gentle continues to negotiate with all opponents until its needs q^{need} are fulfilled. q^{need} is the quantity of external contracts minus that of agreements for the day. We don't set utility function and the decision of Gentle is mainly based on the unit price. The following shows the trading information for the basis of the decision.

$$
\begin{aligned}
i: &\text{ simulation step, } j: \text{ negotiation step, } t^{nego}: \text{ negotiation time} \\
n_{offer}^{contract}: &\text{ number of agreements by Gentle's offer} \\
n_{accept}^{contract}: &\text{ number of agreements by Gentle's accept} \\
p^{max}: &\text{ maximum unit price of the negotiation} \\
p^{min}: &\text{ minimum unit price of the negotiation} \\
p^{best\_contract}: &\text{ the best unit price of the agreements with the opponent} \\
p^{worst\_contract}: &\text{ the worst unit price of the agreements with the opponent} \\
p_{i,j}^{opp\_offer}: &\text{ offer price of the opponent on day } i, \text{ step } j \\
p_i^{best\_selling} &= \max\left(p_{i,0}^{opp\_offer}, p_{i,1}^{opp\_offer}, \ldots, p_{i,j}^{opp\_offer}\right) \\
p_i^{best\_buying} &= \min\left(p_{i,0}^{opp\_offer}, p_{i,1}^{opp\_offer}, \ldots, p_{i,j}^{opp\_offer}\right)
\end{aligned}
$$

1.1 Offering Strategy

Gentle determines the offer unit price p^{offer} and the offer quantity q^{offer} based on some trading information. The symbols $\prec$ and $\succeq$ are defined as the symbols that indicate whether the price is good or not for Gentle. In the cases, $5 \prec 10$ is true for the seller agent, and $5 \succeq 10$ is also true for the buyer agent. s^{offer} is a slack variable related to the offer, and the larger this value, the more bullish the offer. We set a threshold τ that is the criterion for determining whether a given price is bad for Gentle or not.

$$
p^{offer} = \begin{cases}
\dfrac{p^{max} + p^{min}}{2} \times (1 + type \times s_{offer}) & \text{if } n_{accept}^{contract} + n_{offer}^{contract} = 0 \\
p^{worst\_contract} & \text{if } n_{accept}^{contract} \geq 1 \text{ and } p^{worst\_contract} \succeq \tau \\
 & \text{or } n_{accept}^{contract} < 1 \text{ and } n_{offer}^{contract} \geq 1 \\
p^{worst\_contract} \times (1 + type \times 0.1) & \text{if } n_{accept}^{contract} \geq 1 \text{ and } p^{worst\_contract} \prec \tau
\end{cases}
$$

$$
q^{offer} = q^{need}
$$

$$
type = \begin{cases} 1 & \text{if it is a seller} \\ -1 & \text{if it is a buyer} \end{cases}
$$

$$
s_{offer} = 0.2 - 0.5 \times \min\left(\frac{t^{nego}}{0.3}, 1\right)
$$

$$
\tau = \begin{cases}
p^{max} - 19^{-0.2} \times \left(p^{max} - p^{min}\right) & \text{if it is a seller} \\
p^{min} + 19^{-0.2} \times \left(p^{max} - p^{min}\right) & \text{if it is a buyer}
\end{cases}
$$

1.2 Acceptance Strategy

Gentle determines the acceptable unit price p^{offer} based on some trading information. The quantity is not taken into account. s^{accept} in the equation is a slack variable related to acceptance, and the larger this value, the more concessional acceptance. We set a variable r that is the ratio of the change in the opponent's concession rate.

$$p^{accept} = \begin{cases} \max\left(p_i^{best\_selling}, p^{best\_contract} \times (1 - s_{accept})\right) & \text{if it is a seller} \\ \min\left(p_i^{best\_buying}, p^{best\_contract} \times (1 + s_{accept})\right) & \text{if it is a buyer} \end{cases}$$

$$s_{accept} = \begin{cases} 0.2 & \text{if } r \geq 3 \\ 0 & \text{if } r < 3 \end{cases}$$

$$r = \frac{p_{i,j}^{opp\_offer} - p_{i,j-1}^{opp\_offer}}{p_{i,j-1}^{opp\_offer} - p_{i,j-2}^{opp\_offer}}$$

2 Risk Management

To deal with the risk of not being able to agree at all, Gentle makes concessional offers based on the self factor S. Specifically, it makes concessions under the following conditions. Now, we set t^{sim} that represents the simulation time.

1: if $t^{sim} > 0.3$ and $S < 0.5$:

2: $\quad s^{offer} = s^{offer} - 1$

The self factor represents how well Gentle is doing at a specific time. It depends on the agreement ratio (AR) until the given simulation step i and the agreement price (AP) that represents whether Gentle can agree on a good price or not.

$$S = \frac{2}{3}AR + \frac{1}{3}AP$$

$$AR = \begin{cases} \dfrac{\text{number of success simulation steps}}{i} & \text{if Gentle has one or more agreements} \\ 1 & \text{if Gentle has no agreement} \end{cases}$$

$$AP = \begin{cases} \min\left(1, \max\left(0, 0.5 - type \times \dfrac{p^{prev\_contract} - TP}{TP}\right)\right) & \text{if Gentle has one or more agreements} \\ 0.5 & \text{if Gentle has no agreement} \end{cases}$$

$p^{prev\_contract}$: most recently agreement price

TP : trading price

3 Evaluation

We tested Gentle in simulations against *LearningAgent* and *AdaptiveAgent*. The results are shown in Table 1.

Table 1: The test results of Gentle

Agent	score	min	Q1	median	Q3	max
Gentle	1.060164	0.581421	0.964384	1.064991	1.130878	1.705256
LearningAgent	0.967132	0.553072	0.858785	0.958567	1.050838	1.708739
AdaptiveAgent	0.903169	-0.072392	0.833647	0.971782	1.049998	1.146752

The results show that Gentle is equal to or better than the other agents in all scores. Therefore, Gentle outperforms other agents in many cases. The reason for these results is that Gentle takes into account $p^{worst\_contract}$. $p^{worst\_contract}$ is the price that the opponents use as a criterion to determine whether or not to accept the offer. Hence, offering a price close to $p^{worst\_contract}$ makes it easier for the opponents' agreements.