StagHunter: An Automatic Bargaining Agent for Repeated Concurrent Negotiation with Coupled Utilities

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July 2021

1 Introduction

This manuscript presents our agent design for SCML'2021, oneshot track competition.

Agent each day receives a payoff that is a (potentially nonlinear) function of the results of these negotiations. In each simulation an agent will receive a payoff that is a summation of its daily payoffs. And an agent's final score in the tournament will be a truncated mean across all these simulations.

After studying the game mechanism, we highlight several important observations that we consider is insightful to our agent design. Specifically, the daily payoff is coupled across different negotiations, so it maybe hard to separate the negotiations into independent ones. But we can notice that according to the payoff structure,

- For an L_0 agent, its buying profit from an exogenous contract as well as the production cost is fixed. By selling more quantities to an L_1 agent, it may have higher selling profits, but also can induce higher shortfall penalty (if greater than producibility). The higher the selling price, the better.
- For an L_1 agent, its sale profit from an exogenous contract is fixed. If a buying contract from L_0 will not saturate the productivity, then by agreeing to this contract this L_1 agent will have larger buy cost, larger production cost, but less shortfall penalty. On the other hand, if such buy contract saturates the productivity, it will only incur larger buy cost, since now the production cost, shortfall penalty and sale profit are all fixed. The lower the buying price, the better.

2 Agent Design

By the above reasoning we make the following points:

- It is always risky to over-buy/sell a good more than your exogenous contracts. For an L_0 agent the only way to be benefited from an over-sale is to make the price high enough such that it can compensate the disposal penalty. For an L_1 agent, however, we think it never increase the profit by over-buying. By this reasoning, we consider the quantity issue will tend to be decreasing in an opponent's offers, as it will be keep acquiring more and more goods from other agents at my level.
- To reach an agreement in a negotiation we consider it sensible for both agent to concess on the price. For an L_0 agent it should gradually lower the price in its offer, while for an L_1 it should be the opposite. However, we consider combining historical prices information may provide an edge.

We combine these points with the GreedyOneShotAgent design provided by the organizer. We now define some notations.

$AGG\_CONTRACTS$: the set of contracts that have been reached agreement with the other level today so far.

u_i is the utility function of player i. It is a function of $AGG\_CONTRACTS$.

$SECURED$: a variable that record how much quantities are reached agreement totally.

$DEMAND$: Denote the number of demanded quantities. I.e., this is the quantities specified by the exogenous contract minus $SECURED$

$BEST\_PRICE(o)$: the best price (highest for L_0 and lowerest for L_1) encountered during the bargaining process with the opponent o today so far.

$BEST\_PRICE$: the best price across all opponents today so far.

$BEST\_AGG\_PRICE$ the best price agreed across all opponents today so-far.

$ACC\_BEST\_PRICE(o, w)$: the best price of the negotiation results toward opponent o in the past w agreements.

$ACC\_BEST\_AGG\_PRICE(w)$: the best price that was reached agreement across all opponents in the past w agreements.

$MIN\_QUANTITY(o, t)$: the minimum quantity proposed by opponent o in the current bargaining thread in the past t rounds.

We next elaborate our propose strategy (when asked to propose an offer) and respond strategy (when asked to respond to an opponent's counter-offer).

2.1 Respond

When an opponent o propose an offer OFF, we first check whether it has a positive marginal utility improving upon the current $AGG\_CONTRACTS$. I.e., whether $u(AGG\_CONTRACTS \cup OFF) - u(AGG\_CONTRACTS) > 0$. If it is not, then we reject the offer.

Otherwise, we check whether the price issue is a *good price*. If it is, then we accept, otherwise reject.

We will specify what do we mean by *good price* in Sec 2.3.

2.2 Propose

First we determine the quantity issue to be proposed, as we consider it crucial. We let the quantity be $\min(MIN\_QUANTITY(o, 3), \max(2/3 \times DEMAND, 1))$. Our interpretation is: the proposed quantity should be at most some proportion of its own left demand (we choose 2/3); meanwhile to increase chance of being accepted, it shouldn't be too much larger than the opponent's left demand (which we use $\min(MIN\_QUANTITY(o, 3)$ as an indicator.)

After have chosen this quantity, we first find a *good price* (Sec 2.3). Then starting from this *good price*, we increasing it til the *best price* (which is the maximum prices for L_0 and minimum for L_1), until the one that makes the current marginal utility positive. If we have not found such price, we just set the price as the best price. Then we return this offer as the proposal.

2.3 Good Price and Price Concession Strategy

Now we define what do we mean by a *good price* at a certain round of bargaining process. Intuitively, for an L_0 agent its acceptation/proposing price should be lower and lower as the negotiation continues (higher and higher for L_1). Being consist with GreedyOneShotAgent, we use a concession factor e to model such concession effect, combining with the prices information encountered so far.

To be more specific, for an L_0 agent, we consider a range of price $[mn, mx]$ where mx are the maximum price possible and mn is dynamically changed. We let $mn = \max\{(1+\zeta_1)mx, \min\{(1+\zeta_2)BEST\_PRICE(o, d), (1+\zeta_3)BEST\_PRICE(d)), (1+\zeta_4)BEST\_AGG\_PRICE(d), (1+\zeta_5)ACC\_BEST\_PRICE(o, 3$ $\zeta_6)ACC\_BEST\_AGG\_PRICE(3)\}\}$. I.e., the prices should be at least some proportion of the best prices encounted so far.

For now we let $\zeta_1 = 0.1, \zeta_2 = 0.15, \zeta_3 = 0.2, \zeta_4 = 0.15, \zeta_5 = 0.15, \zeta_6 = 0.25$

And define $th = ((T-t)(T))^e$, then we say a price p is good if $p - mn \geq th \cdot (mx - mn)$, where t is the round index of a bargaining and T being the maximum round of bargaining.

And when proposing, we define a good price as $mn + th(mx - mn)$.

For L_1 it is similarly defined.

For the concession exponents, each day we just re-initialize an exponent against each opponent via a uniform distribution between 0.01 and 0.7.