Designing a Negotiating Party

Group 29

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2.E

HardHeaded Frequency Model The issue with the current *Hard-Headed Frequency Model* is that it does not take the different rounds of the negotiation into account. That is, the estimated issue weights and issue values are updated with a coefficient that is constant over time. Many agents will use a bidding strategy starting with bids that yield a large utility for itself. Over time, if an agreement is not yet reached, concessions will be made resulting in bids that generate lower utilities. Hence, observing differences between received bids early in the negotiations, reveal more information about the underlying issue weights and values of the opponent.

Issue weights When estimating the issue weights, the *HardHeaded Frequency Model* increases the estimated issue weights of an issue in case the issue values remain unchanged using a parameter n. This parameter is constant over time, implying that a changed value in the last round of a negotiation is just as determinative as changing a value from turn one over to turn two.

Issue values When estimating the issue values, the *HardHeaded Frequency Model* increases the (unnormalised) estimated issue values if the issue value is present in the bid by incrementing by a given parameter. This parameter (usually equal to 1) is fixed and therefore also constant over time.

Time-dependent HardHeaded frequency model We propose to adapt the *Hardheaded Frequency Model* by adding a time parameter $T \in [0, 1]$, with $T = 0$ and $T = 1$ denoting the first round and the deadline of the negotiation, respectively. This parameter is used in estimating both the issue weights and the issue values as follows:

Issue weights We adapt the formula of the standard *HardHeaded frequency model*, $W_i^{new} = W_i^{old} + n$ for issue i, to $W_i^{new} = W_i^{old} + n \times (1-T)^{\gamma}$. $(1-T)^{\gamma}$ is a correction term over time, yielding the original formula if $T = 0$, and yielding $W_i^{new} = W_i^{old}$ when T approaches 1, for all values of γ. The correction term is polynomially decreasing over γ ($\gamma = 1$ yields a linear slope). This implies that we assign significantly more value to bids near the start of the negotiation. *We currently use* $\gamma = 2$.

Issue values Instead of counting the number of appearances for every issue values throughout the negotiation and normalising this, we once again want to assign larger values to frequently occurring issue values at the start of the negotiation. We evaluate the appearing issue values per receiving bid by $\lceil (D(1-T)^{\zeta} \rceil$, with D denoting the deadline of the negotiation, in terms of rounds (that is, the round for which $T = 1$). Hence, in the first round of the negotiation, implying $T = 1$, every appearing issue value is counted D times, before being normalized. *We currently use* $\zeta = 2$.

2.F

So far, in our bidding strategy, we have not considered the estimated utility of our opponent. We had generated a list of all bids yielding a personal utility above a given threshold. Every round, one bid will be offered at random. We aim to improve the proportion of accepted bids by using the described opponent model, while still only sending bids that result in a high own utility.

Now, instead of choosing a random bid from the list, we rank the list based on the *estimated Nash products*. We define the estimated Nash products of bid i at time T as $\pi_{iT} = u_i^A u_{iT}^B$. With B as the opponent, A as ourselves and u as the utility. Note that u_i^B is known and constant over time. Since u_{iT}^B, denoting the utility of bid i at time T of the opponent, is an estimated value, π_{iT} is an estimation as well. However, it still holds that if $\pi_{iT} > \pi_{jT}$ then $u_i^A > u_j^A$ or $u_{iT}^B > u_{jT}^B$ for bids i, j. This means that if we consider to send a bid i yielding a smaller personal utility than bid j, we have estimated that bid i is preferred by our opponent.

We use the estimated Nash products of all bids that exceed our personal utility threshold as follows:
Instead of constantly selecting the first bid of the list, we send a bid based on time, our own utility and the Nash product. Because we base the bidding on time, the initial bids that we send have a high utility for us. Over time, when we get more information about our opponent we have a higher chance of sending him a Nash product bid. This happens with the formula: $l = (1 - time) * len(totalbids)$. This l(=length of the sublist) is then used to pull a random bid from the sublist of all the sorted bids. If $l = 0$ it will pick the highest sorted bid. This way, when time passes, there is a higher chance to pull a better bid for the opponent, so on average we concede to the opponent. A more formal formulation summarizes the strategy in equation (1) , with bid index r from the sorted Nash product list. And the length of the bids above the target (which is an set threshold), $|S|$.

$$r \sim U[0, (1-T) \times |S|] \tag{1}$$