Predicting Automated Negotiation Bandwidth Usage at the Edge of the Network

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***Abstract*—Automated negotiation can be an efficient method for resolving conflict and redistributing resources in a coalition setting. Automated negotiation has already seen increased usage in fields such as e-commerce and power distribution in smart girds. However, significant barriers to more widespread adoption remain. For example, consumption of bandwidth, which can be problematic in real environments, especially at the edge of a network. The ultimate outcome of this research is to develop a negotiation agent that can leverage exchanging constraints during a negotiation to reduce the number of messages needed to be exchanged before the negotiation terminates (either successfully or unsuccessfully). In this paper we take a probabalistic approach and show that the probability that a proposal is acceptable to both of the agents can predict the number of messages necessary for the negotiation. This can provide valuable insight into the difficulty of negotiations and a measure for effectiveness that is under-explored in the current literature.**

***Index Terms*—Automated Negotiation, Constraints, Reasoning about Uncertainty**

I. Introduction

Automated negotiation can be an efficient method of resolving conflict and redistributing resources in a coalition setting. Automated negotiation has already seen increased usage in fields such as e-commerce and power distribution in smart girds. However, one of the most common protocols for automated negotiation, Alternating Offers Protocol, discussed in more detail in the next section, can place a heavy burden on the available bandwidth because of the number of messages that have to be exchanged. While simply using protocols that inherently restrict the number of messages that can be exchanged, such as in, [1], can help alleviate this problem, they come with their own drawbacks. For example, it can involve eagerly disclosing preference information, such as in [3], which is undesirable in environments where cooperation cannot be guaranteed. Conversely, more elaborate protocols that include more complex reasoning can incur significant computational overhead. All of these facts are problematic when considering low recourse computation at the edge of a network, for example by Internet Of Things (IOT) devices. Therefore, it is the goal of this research to develop a negotiation protocol that can be utilised by low recourse devices and is suitable to both cooperational and adversarial negotiations. This work makes the first contribution towards such a method by presenting a novel method for estimating the number of messages that will have to be exchanged before a negotiation terminates, either successfully or not, for the purpose of performance evaluation. We do this by considering the probability that the first proposal an agent proposes is also acceptable to the other agent. We show that this probability is a good predictor of the number of messages, and therefore offers a good way of measuring performance in terms of messages exchanged.

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II. Background

An automated negotiation consists of several components: The *negotiation setting* describes the entire negotiation. Its main components are the agents, the *negotiation protocol* and the *negotiation scenario*. The negotiation protocol details the methods of communication. In this work, it is assumed that both agents adhere to the same protocol. One of the more well-known protocols is the Alternating-Offers Protocol (AOP). In this protocol, the two agents take turns making offers, or bids to each other until one of the agents accepts [2]. When we refer to *Proposal Based Negotiation* (PBN) we refer to negotiations that utilise AOP. The negotiation domain consists of the matters being discussed in the negotiation, meaning that the domain comprises the semantic part of the interaction. Formally we say that the *negotiation domain*, *negotiation space* or *outcome space*, which is usually denoted as Ω, is the product of at least one *issue*. An issue, denoted Λ, is a countable set whose elements are called *values*. Each issue represents one matter that needs to be agreed upon, and the values represent possible assignments. When a negotiation consists of N identical issues we may write $\Omega = \Lambda^N$, in which case we write M for the number of values per issue. A *proposal* is a vector $\omega \in \Omega$, representing a possible assignment to the issues being proposed. We will also denote the proposal that was sent in round t as ${}^t\omega$ One common way of calculating the utility of an offer is by using *linear additive functions* for which it holds that for any $\omega \in \Omega$ where Ω consists of n issues, the following equation holds [2]

$$u(\omega) = \sum_{i=1}^{n} w_i e_i(\omega_i). \quad (1)$$

Here w_i are normalised weights representing the relative importance of each issue, often referred to as the *importance weights* of an agent. Agents may also specify what is called the *reservation value*, denoted as ρ, which represents the minimum amount of utility a proposal must reach to be accepted by the agent. An illustration of a toy negotiation is depicted in Figure 1.

III. Research Method

To demonstrate that the probability that the first proposed offer is acceptable to both parties is indeed a good indicator for the number of messages the negotiation will need, we use an empirical analysis of simulated negotiations. For the purposes of this experiment we implemented negotiation agents that randomly sample proposals from the space until they find one that is acceptable to them. To demonstrate a connection between the probability and the number of messages exchanged we generate negotiation domains, adjusting the utility functions of the agents to control the number of acceptable proposals. Since the agents employ rejection sampling to find acceptable proposals, the probability that an offer will be accepted is equal to the ratio of offers that is acceptable to both agents and the number of offers that are acceptable to the agent generating the proposal. Simulations of negotiations using those generated scenarios are run. Since the agents do not yet have termination rules, a timeout mechanism after 200 rounds or 1000 samples per offer was added. When these limits are reached the negotiations is simply terminated without success. For the purpose of this experiment, all importance weights were kept uniform. To vary the number of acceptable proposals, we used two pairs of parameters, associated with each agent. The first parameter is the reservation value, denoted as ρ, expressed as a percentage of the maximum possible utility for that agent. The second parameter, called τ is an artificial boundary in the utility function, denoting that values on one side of the boundary are worthless, and the values on the other side are all equally preferred. This can range from 0 to M. Whether the values on the left or the right are preferred is always mirrored for the two agents to create a sense of opposing interests. A visualisation of these utility functions can be seen in Figure 1.

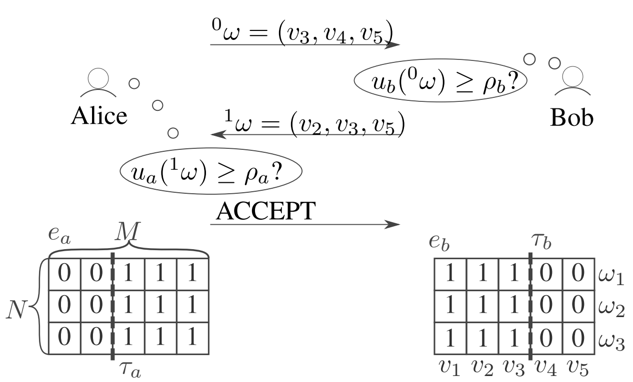

Fig. 1. A visualisation of the agents negotiating and their utility functions. Note that in this case both utility functions are linear additive so they can be represented as a matrix. All importance weights are uniform.

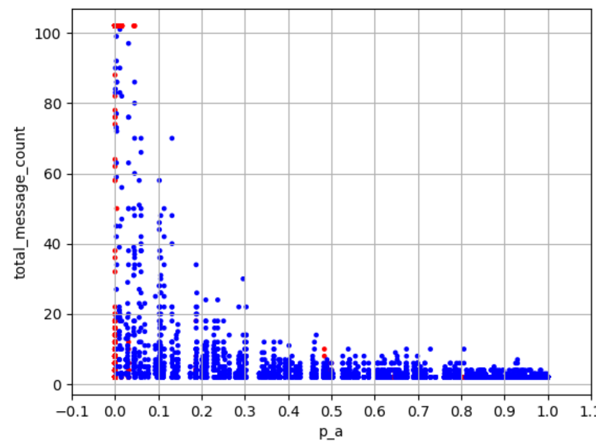

Fig. 2. A figure showing the total number of messages exchanged in a simulation as a function of the probability that the first message is accepted.

Note that the agents have different values for τ which means that both value any issue being assigned as v_3 as 1.

IV. Results

For this experiment we fixed $N = 5, M = 7$ and the ρ was samples 20 equally spaced points across the unit interval. Finally both of the τ parameters varied from 0 to M. Ultimately 25601 simulations as discussed above were run, and the number of messages that were exchanged before termination, were recorded. The results of these simulations are visualised in figure 2. As can be seen the number of messages needed exhibits an exponential decay behaviour as a function of the probability that the first proposal is accepted. The colours in the graph represent whether the negotiation was successful or not. We can see that in the vast majority of cases where the probability was non-zero, the negotiation succeeded. However it can also be seen that a few of the negotiations timed out after the maximum number of rounds. Negotiations that failed before the maximum number of rounds, failed because either of the agents was unable to find suitable proposals. Therefore this we conclude that this probability, can provide a good measure of difficulty of negotiations.

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