# Acceptance Conditions in Automated Negotiation*

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## Abstract

In every negotiation with a deadline, one of the negotiating parties has to accept an offer to avoid a break off. A break off is usually an undesirable outcome for both parties, therefore it is important that a negotiator employs a proficient mechanism to decide under which conditions to accept. When designing such conditions one is faced with the acceptance dilemma: accepting the current offer may be suboptimal, as better offers may still be presented. On the other hand, accepting too late may prevent an agreement from being reached, resulting in a break off with no gain for either party.

Motivated by the challenges of bilateral negotiations between automated agents and by the results and insights of the automated negotiating agents competition (ANAC), we classify and compare state-of-the-art generic acceptance conditions. We focus on *decoupled* acceptance conditions, i.e. conditions that do not depend on the bidding strategy that is used. We performed extensive experiments to compare the performance of acceptance conditions in combination with a broad range of bidding strategies and negotiation domains. Furthermore we propose new acceptance conditions and we demonstrate that they outperform the other conditions that we study. In particular, it is shown that they outperform the standard acceptance condition of comparing the current offer with the offer the agent is ready to send out. We also provide insight in to why some conditions work better than others and investigate correlations between the properties of the negotiation environment and the efficacy of acceptance conditions.

## 1 Introduction

Negotiation is an important process to reach trade agreements, and to form alliances or resolve conflicts. The field of negotiation originates from various disciplines including artificial intelligence, economics, social science, and game theory (e.g., [2, 16, 20]). The strategic–negotiation model has a wide range of applications, such as resource and task allocation mechanisms, conflict resolution mechanisms, and decentralized information services [16].

A number of successful negotiation strategies have already been established both in literature and in implementations [6, 7, 12, 13, 19]. And more recently, in 2010 seven new negotiation strategies were created to participate in the first automated negotiating agents competition (ANAC 2010) [3] in conjunction with the Ninth International Conference on Autonomous Agents and Multiagent Systems (AAMAS-10). During post tournament analysis of the results, it became apparent that different agent implementations use various conditions to decide when to accept an offer. In every negotiation with a deadline, one of the negotiating parties has to accept an offer to avoid a break off. Therefore, it is important for every negotiator to employ a mechanism to decide under which conditions to accept. However, designing a proper acceptance condition is a difficult task: accepting too late may result in the break off of a negotiation, while accepting too early may result in suboptimal agreements.

The importance of choosing an appropriate acceptance condition is confirmed by the results of ANAC 2010 (see Table 1). Agents with simple acceptance criteria were ranked at the bottom, while the more sophisticated time- and utility-based criteria obtained a higher score. For instance, the low ranking of *Agent Smith* was due to a mistake in the implementation of the acceptance condition [27].

Despite its importance, the theory and practice of acceptance conditions has not yet received much attention. The goal of this paper is to classify current approaches and to compare acceptance conditions in an experimental setting. Thus in this paper we will concentrate on the final part of the negotiation process: the acceptation of an offer. We focus on decoupled acceptance conditions: i.e., generic acceptance conditions that can be used in conjunction with an arbitrary bid-

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| **Rank** | **Agent** | **Acceptance method** |
|---|---|---|
| 1 | *Agent K* | Time and utility based |
| 2 | *Yushu* | Time and utility based |
| 3 | *Nozomi* | Time and utility based |
| 4 | *IAMhaggler* | Utility based only |
| 5 | *FSEGA* | Utility based only |
| 6 | *IAMcrazyHaggler* | Utility based only |
| 7 | *Agent Smith* | Time and utility based |

Table 1: An overview of the rank and acceptance conditions of every agent in ANAC 2010.

ding strategy.

Our contribution is fourfold:

1. We give an overview and provide a categorization of current decoupled acceptance conditions.
2. We introduce a formal negotiation model that supports the use of arbitrary acceptance conditions.
3. We compare a selection of current generic acceptance conditions and evaluate them in an experimental setting.
4. We propose new acceptance conditions and test them against established acceptance conditions, using varying types of bidding techniques.

## 2 Experiments

In order to experimentally test the efficacy of an acceptance condition, we equipped a set of agents with an acceptance condition, and measured its result against other agents by averaging the total accumulated utility over all trials on various negotiation domains. We have surveyed existing negotiation agents to examine the acceptance criteria that they employ. A description of the acceptance conditions that we tested is listed in Table 2.

### 2.1 Existing Acceptance Conditions

We give a short overview of decoupled acceptance conditions used in literature and current agent implementations. We are primarily interested in acceptance conditions that are not specifically designed for a single agent. We do not claim the list below is complete; however it serves as a good starting point to categorize current decoupled acceptance conditions. We surveyed the entire pool of agents of ANAC 2010, including *Agent K* and *Nozomi* [25], *Yushu* [1], *IAM(crazy)Haggler* [5], *FSEGA* [24] and *Agent Smith* [27]. We also examined well-known agents from literature, such as the Trade-off agent [7], the Bayesian learning agent [11], *ABMP* [13], equilibrium strategies of [9], and time dependent negotiation strategies as defined in [22], i.e. the Boulware and Conceder tactics.

Table 3: A selection of existing decoupled acceptance conditions.

| **AC** | $\alpha$ | $\beta$ | **Agent** |
|---|---|---|---|
| $\mathbf{AC}_{\text{next}}(\alpha, \beta)$ | 1 | 0 | *FSEGA*, Boulware, Conceder, Trade-off, Equilibrium strategies |
| | 1.02 | 0 | *IAM(crazy)Haggler* |
| | 1.03 | 0 | *Bayesian Agent* |
| $\mathbf{AC}_{\text{const}}(\alpha)$ | 1 | - | *FSEGA* |
| | 0.9 | - | *Agent Smith* |
| | 0.88 | - | *IAM(crazy)Haggler* |
| | **T** | | |
| $\mathbf{AC}_{\text{time}}(T)$ | 0.92 | - | *Agent Smith* |

Listed in Table 3 is a selection of generic acceptance conditions found.

Some agents also use logical combinations of different acceptance conditions at the same time. This explains why some agents are listed multiple times. We will not focus on the many possible combinations of all acceptance conditions that may thus be obtained; we will study the basic acceptance conditions in isolation with varying parameters. However in addition to this we have studied a small selection of combinations. We leave further combinations for future research.

As can be seen from Table 3, in our sample the most commonly used acceptance condition is $\mathbf{AC}_{\text{next}} = \mathbf{AC}_{\text{next}}(1, 0)$, which is the familiar condition of accepting when the opponent's last offer is better than the planned offer of the agent.

### 2.2 Experimental Setup

For our experimental setup we employed Genius (General Environment for Negotiation with Intelligent multi-purpose Usage Simulation) [17]. This environment, which is also used in ANAC, helps to facilitate the design and evaluation of automated negotiators' strategies.

We use the negotiation tactics that were submitted to ANAC 2010 [3]. ANAC is a negotiation competition aiming to facilitate and coordinate the research into proficient negotiation strategies for bilateral multi-issue negotiation.

## 3 Results and Conclusion

A selection of the experimental results are summarized in Table 4. We observe that designing an effective acceptance condition is challenging because of the acceptance dilemma: better offers may arrive in the

| **Acceptance Condition** | **Description** |
|---|---|
| $\mathbf{AC}_{\text{const}}(\alpha)$ | Accept when the opponents bid is better than $\alpha$. |
| $\mathbf{AC}_{\text{next}}$ | Accept when the opponents bid is better than our *upcoming* bid. |
| $\mathbf{AC}_{\text{time}}(T)$ | Accept when time $T$ has passed. |
| $\mathbf{AC}_{\text{combi}}(\text{MAX})$ | Accept when the current offer is the best in a previous time window. |
| Built-in mechanism | The acceptance condition that was originally present in the agents. |

Table 2: Acceptance conditions employed by various agents.

| **Acceptance Condition** | **Agreement %** | **Average utility of agreements** | **Total avg** |
|---|---|---|---|
| $\mathbf{AC}_{\text{combi}}(\text{MAX})$ | 99% | 0.679 | 0.675 |
| Built-in mechanism | 82% | 0.768 | 0.627 |
| $\mathbf{AC}_{\text{time}}(0.99)$ | 99% | 0.622 | 0.618 |
| $\mathbf{AC}_{\text{next}}$ | 72% | 0.787 | 0.567 |
| $\mathbf{AC}_{\text{const}}(0.8)$ | 38% | 0.851 | 0.324 |
| $\mathbf{AC}_{\text{const}}(0.9)$ | 26% | 0.935 | 0.239 |

Table 4: Utility scores of agents equipped with an acceptance condition

future, but waiting for too long can result in a break off of the negotiation, which is undesirable for both parties, especially in the setting of one-shot negotiations. In short:

*(The acceptance dilemma)*

$$\text{Total average utility} = \text{Agreement percentage} \times \text{Average utility of agreements.}$$

This formula captures the essence of the acceptance dilemma: accepting bad to mediocre offers yields more agreements of relatively low utility. While accepting only the best offers produces less agreements, but of higher utility. Acceptance conditions will have to find a balance between both goals.

$\mathbf{AC}_{\text{time}}(T)$, with $T$ close to 1 is a sensible criterion to avoid a break off at all cost. However, the resulting deal can be anything, so the resulting agreement utility is very low. $\mathbf{AC}_{\text{const}}(\alpha)$ is not very advantageous to use, as the choice of the constant $\alpha$ is highly domain-dependent. In very cooperative domains, $\mathbf{AC}_{\text{const}}(\alpha)$ will accept an offer that can be *relatively* bad, i.e. it could have done much better. On the other hand, in highly competitive domains, it may simply 'ask for too much' and may rarely obtain an agreement.

The standard condition $\mathbf{AC}_{\text{next}}$ is often used by negotiating agents. However, from our results, it is apparent that it does not always yield optimal agreements. We have devised more sophisticated acceptance conditions by combining existing ones such as $\mathbf{AC}_{\text{next}}$ and $\mathbf{AC}_{\text{time}}(T)$ into new ones; one example being $\mathbf{AC}_{\text{combi}}(\text{MAX})$. These combinations outperformed the other conditions we have tested.

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