# Rational Strategy to Perform Automated Bilateral Negotiation 

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ABSTRACT: Automated negotiation is a process by which competitors aim to reach agreement by using suitable strategies. This paper aims to enhance negotiation process by using theoretical techniques that help agents to reach final agreement with shorten trade time. The purpose is to succeed negotiation process with better resource utilization.

The proposed techniques are based on game theory to support the decision of rational agents to offer the better acceptable proposal in a specific negotiation thread. The designed model has been evaluated by extensive experiments.

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## 1. Introduction

Automated negotiation is a key form of dynamic interaction between two or more autonomous software agents, to reach mutually agreement in furtherance of their users' interests.

Many researches [1] deal with negotiation's problems by providing theoretical techniques to enhance negotiation outcomes like as utility gain and time spent on negotiation.

Binmore and Vulkan show [2] the impact of game theory to offer gain in programming agent within the ADEPT (Advance Decision Environment for Process Tasks) project.

Kraus develops [3] a set of protocols that engage software agents in strategic reasoning to reach final agreement on matter of common interest.

Faratin and al [4] develop a heuristic computational model of the trade-off strategy and show that it can lead to an increased social welfare of the system.

In all these examples, the involved agents are self-interested by attempting to get the better deal for only themselves.
Our work differs from the others by taking into consideration the others objectives when making a decision to reach mutually beneficial compromise. Precisely, we are interested in developing autonomous agent based on rational reasoning, to perform negotiation outcomes.
negotiation, section III presents experimentation results, and finally section IV presents the conclusion.

## 2. Rational Reasoning to Perform Automated Negotiation

### 2.1 Automated bilateral negotiation

Negotiation has been for decades, extensively discussed in game theoretic, economic, and management science literatures. Recent growing interest in electronic commerce has given increased importance to automated negotiation [5].

An automated negotiation [6] is the process by which a group of autonomous agents communicate with one to try and come to a mutually acceptable agreement on some matter by resolving conflicting purposes.

In the present paper, we limit our study to automated bilateral negotiation, which is a straightforward iterative process between two software agents having conflicting interests.

Iteration (a round) is composed of an agent's offer and the adversary counter-offer. The final state can be accepting or rejecting the last offer with respectively zero or no-zero outcomes for both agents (see Figure 1).


Figure 1. Bilateral negotiation's rounds
The parameters, presented in the figure1, $\mathrm{P}_{1}^{\mathrm{r}}$ and $\mathrm{P}_{2}^{\mathrm{r}}$ are respectively the player1's and the player2's reserved values.
To reach agreement one agent must concede to agreement area delimited by the respective reserved values of the two players. So each agent has to predict the advisor's strategy including his reserved value to attain agreement zone.

The present study aims to model a rational agent, based on game theory that takes into consideration the advisor's objectives and preferences in each decision making. The rational agent 'end is to estimate agreement zone throw historic transaction to find a wished compromise with his rival.

### 2.2 Rational reasoning

Evidence from theoretical analysis and from observations of human interactions suggests that "If decision makers can somehow
take into consideration what other agents are thinking and furthermore learn during their interactions how other agents behave, their payoff might increase" [7].

As a theoretic technique to perform rational reasoning [8], we refer to game theory that allows agent to achieve desired goals within the limit of the rival's preferences. This technique defines a stable situation satisfying the players' interests [9] called equilibrium state; this later denotes the mutual players 'agreement.An equilibrium state can be expressed as a system condition in which competing interests are satisfied, so that no player is involved to deviate to another state.

In the present work, before making decision rational agent must predict the advisor's strategy to offer a proposal that satisfy mutually the two players so that to guarantee a final commonly satisfying compromise.

The rational model's objective is to predict an equilibrium offer integrating the estimated opponent‘s preferences in each round.
In this context, the bilateral negotiation can be presented by a sequential game tree (see Figure 2); in which a node presents a player's decision-making task that can be one of the following actions:

- Accepts and calculates the generated gain from the last proposal,
- Refuses and have no gain,
- Counter-proposes a new proposal.


Figure 2. Bilateral game negotiation

As presented by figure bilateral negotiation is represented by a game between player 1 and player 2 each one has o set of preferences and objectives to reach. In the presented case the (player1's players' objectives is to maximize respectively utility) and (player2's utility).

By Receiving a proposal $\mathrm{P}^{\mathrm{i}}(\mathrm{i}=1$ or 2$)$ an agent j outcomes one of the following decision:

- : Accepts the proposal $\mathrm{P}^{\mathrm{i}}$ and then the final player1 and player2's utilities are respectively $\mathrm{U}_{1}^{\mathrm{k}}$ and $\mathrm{U}_{2}^{\mathrm{k}}\left(\mathrm{k}\right.$ is the $\mathrm{k}^{\prime}$ th round $)$.
- : Refuses the proposal $\mathrm{P}^{\mathrm{i}}$ and then the finalplayer1 and player2's utilities are zero for both; $\mathrm{U}_{1}^{\mathrm{k}}=\mathrm{U}_{1}^{\mathrm{k}}=0$.
- $\mathrm{P}^{\mathrm{j}}$ : Proposes (or counter-propose) the offer $\mathrm{P}^{\mathrm{j}}$

The player1 and player2 utilities are computed respectively as follow:
$-\mathrm{U}_{1}^{\mathrm{k}}=\frac{\mathrm{P}_{1}^{\mathrm{r}}-\mathrm{P}^{\mathrm{k}}}{\mathrm{P}_{1}^{\mathrm{r}}-\mathrm{P}^{\mathrm{o}}}$ : The utility of the playerl at the round k by accepting the proposal $\mathrm{P}^{\mathrm{k}}$ :
$\bigcirc \mathrm{P}^{\mathrm{k}}$ : the last proposal
$\bigcirc \mathrm{P}_{1}^{\mathrm{r}}$ : the reserved (limit)player 1'proposal
$\bigcirc \mathrm{P}_{1}^{0}$ : the initial player1'proposal
$-U_{2}^{k}=\frac{P^{k}-P_{2}^{r}}{P^{\mathrm{o}}-\mathrm{P}_{2}^{\mathrm{r}}}$ : The utility of the player2 at the moment k by accepting the proposal $\mathrm{P}^{\mathrm{k}}$ :
$\bigcirc \mathrm{P}^{\mathrm{k}}$ : the last proposal
$\bigcirc \mathrm{P}_{2}^{\mathrm{r}}$ : the reserved (limit) player2's proposal
○ $\mathrm{P}_{2}^{0}$ : the initial player2's proposal

This iterative game process can end without failure if and only if the both parties find a compromised situation that satisfies their private utilities. This condition is satisfied if at least one of both parties takes into account the preferences of his opponent in his decision-making and offers a proposition $P^{*}$ that optimizes his utility and his opponent's utility: this offer forms an equilibrium state of the bilateral game negotiation.

The equilibrium's point $P^{*}$ is function of reserved proposals of the two players, but in a realistic environment these values are unknown by both members.

This unknown information leads to divide the bilateral negotiation into a set of sequential Subgames to find potential equilibrium solutions inside each Subgame.

### 2.3 Subgame's Equilibrium

A Subgame solution subdivides sequential game on a set of consecutive and independent sub-trees; each one contains a complete information about the last players 'strategies (actions) as well as their last offer and counter-offer (see Figure 3).

A Subgame is defined as a subset of a game; meeting the following criteria: [10]

1. It contains a single initial node that is the last rejected decision.
2. It contains all the nodes that are successors of the initial node.
3. It contains all the nodes that are successors of any node it contains.
4. If a node in a particular information set is in the Subgame then all members of that information set belong to the Subgame.

A Subgame perfect equilibrium is a refinement of a Nash equilibrium [11] used in dynamic games.
A strategy profile is a Subgame perfect equilibrium if it represents Nash equilibrium of every Subgame of the original game. More informally, this means that:

- If the players played any smaller game that consisted of only one part of the larger game,
- and players 'behavior represents Nash equilibrium of that smaller game,
- then their behavior presents a Subgame perfect equilibrium of the larger game.


Figure 3. The Subgames'negotiation

## - Nash Subgame-perfect equilibrium

Nash equilibrium is said to be Subgame perfect, if and only if, it implies Nash equilibrium point in every Subgame of the all game. A Subgame must be a well-defined game when it is considered separately. That is:

- it must contain an initial node,
- and all the moves and information sets from that node on must remain in the Subgame.

In the present bilateral game negotiation, at the beginning of each round, the rational agent knows all the previous offers, which have been rejected, and makes a current offer. This later is based on Nash Subgame-perfect equilibrium solution.

The Nash solution assigned to bilateral negotiation's Subgames presents the equilibrium offer that maximizes the following product:

$$
\max \left[\left|\left(u_{b}\left(P^{*}\right)-d_{b}\right)\right| *\left|\left(u_{s}\left(P^{*}\right)-d_{s}\right)\right|\right]
$$

Where:

- $P^{*}$ : the equilibrium offer (accepted offer)
$-u_{b}\left(P^{*}\right)$ : The rational agent's utility the equilibrium offer $\mathrm{P}^{*}$.
$-u_{s}\left(P^{*}\right)$ : The opponent's utility by accepting ? the offer $\mathrm{P}^{*}$.
$-d_{b}$ : The rational agent's utility from the rejected previous offer.
$-d_{s}$ : The opponent's utility from the rejected previous offer.

Considering that the last rejected offer is the opponent's proposal $P_{t}{ }^{s}$ (the opponent's offer at time t ), the Nash's equation solution becomes:

$$
P^{*}=P_{t}^{s}
$$

This solution is not feasible for the rational agent, since it only favors the opponent's preference. Also it seems unreasoned since the rational agent would counter-propose into the Subgame the last proposed offer of his opponent (rejected offer).

## - Nash's solution Improvement

The principle is to find, inside each Subgame, a potential subset of winning solutions, contributing to satisfy the objectives and preferences of both players.

In other words, the solution is to find an equilibrium state that satisfy a set of rational agent's constraints, answering to some of his main preferences. These constraints can be described as follows:

$$
\begin{gathered}
P^{*} \leq P_{b}^{r} \\
P^{*} \leq P_{t}^{s} \\
u_{b}\left(P^{*}\right) \geq \mid u_{b}\left(P_{t}^{s}\right)
\end{gathered}
$$

With:

- $P_{b}^{r}$ : The reserved (limit) rational agent's offer.
- $P^{*}$ : The equilibrium offer.
$-\mathrm{u}_{b}\left(P^{*}\right)$ : The rational agent's utility from the equilibrium offer $P^{*}$.
- $u_{b}\left(P_{t}^{s}\right)$ : The opponent's utility from the last offer $P_{t}^{s}$ at time t .

Equilibrium offer $P^{*}$ would then satisfy the following constrained system:

$$
\begin{gathered}
\max \left[\left|\left(u_{b}\left(P^{*}\right)-d_{b}\right)\right| *\left|\left(u_{s}\left(P^{*}\right)-d_{s}\right)\right|\right] \\
\text { Under constraint }\left\{\begin{array}{c}
P^{*} \leq P^{r} \\
P^{*} \leq P^{s} \\
u_{b}\left(P^{*}\right) \geq \mid u_{b}\left(P^{s}\right)
\end{array}\right\}
\end{gathered}
$$

The solution of this system by using the Kuhn-Tucker[12,13] theory is:

$$
P^{*}=\min \left\lfloor\left(2 * P_{r}^{b}-P_{t}^{s}\right), P_{t}^{s}, P_{r}^{b}\right\rfloor
$$

To validate experimentation. our solution we establish a set of experimentation.

## 3. Experimental Study

The aim of experimentation is to evaluate rational strategy compared with Time Dependent strategy during a bilateral negotiation simulation between a rational buyer and a Time Dependent seller [15], for the price of a good.

The offer of a Time Dependent's seller is defined by:
$P_{s}^{\frac{1}{\beta}}=\min _{s}+\left(1-\alpha_{s}(t)\right) \cdot\left(\max _{s}-\min _{s}\right)$
$\quad P_{s}=\min _{s}+\left(1-\alpha_{s}(t)\right) \cdot\left(\max _{s}-\min _{s}\right)$
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$\beta<1$ then the agent is aggressive otherwise the agent is conciliatory.

- T : the negotiation's limit time
- min $_{\mathrm{s}}$ : The minimal seller's price (reserved value)
- max ${ }_{\mathrm{s}}$ : The maximal seller's price

To evaluate the rational strategy, we experiment the following measures:

1. The average utilities $\left(\mathrm{U}_{\mathrm{i}}\right)$ : denote the intrinsic agents 'benefit from negotiation's final outcome.

$$
\begin{aligned}
& \text { Buyers' Utilities: } U_{b}=\frac{\max _{b}-P^{*}}{\max _{b}-\min _{b}} \\
& \text { Sellers' Utilities: } U_{s}=\frac{P^{*}-\max _{s}}{\max _{s}-\min _{s}}
\end{aligned}
$$

$P^{*}$ : The agreed price (accepted by the two parts).
If no deal is made then $U_{s}=U_{b}=0$
2. The average round's number (Round_moy) to reach agreement.

$$
\text { Round_moy }=\frac{\sum \text { round' numbers }}{\sum \text { sussful cases }}
$$

3. The agreement rate (Agr_rate):

$$
\text { Agr_rate }=\frac{\sum \text { sussful cases }}{\sum \text { all cases }}
$$

Time dependent strategy is subdivided on three tactics according to the agent's competitive, neutral or cooperative behavior(see Table 1):

| Tactics <br> classes | Name | Abbreviation | Parameters |
| :--- | :---: | :---: | :---: |
| Dep. time | conciliatory | C | $\beta \in\{0.01,0.2\}$ |
| Dep.time | neutral | N | $\beta=1.0$ |
| Dep. time | aggressive | A | $\beta \in\{20.0,40.0\}$ |

Table 1. Negotiation tactics
In different experimentations we instantiate variables as followed:
$-\mathrm{T}^{\mathrm{b}} \max =\mathrm{T}^{\mathrm{s}} \max (\in[20100])$
$-\min _{\mathrm{s}}=\min _{\mathrm{b}}=10$;
$-\theta^{b} \in\left[\begin{array}{ll}10 & 90\end{array}\right]$
$-\theta^{\mathrm{s}} \in[10,90]$
$-\partial=0$

### 3.1 Experiences

Experiences focus the impact of players' behaviors (such as conciliatory, neutral, or aggressive) on the negotiation's process and
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Figure 4. Average utilities
outcomes.
Three experiences are studied:

1. First experience: Rational buyer (Rb) / Aggressive time Dep. seller (As)
2. Second experience: Rational buyer (Rb) / Neutral time Dep. seller (Ns)
3. Third experience: Rational buyer ( Rb ) / conciliatory time Dep. seller (As)

### 3.2 Average utilities of all negotiations'cases (successful \& failed)

According to the Figure 4, we notice the superiority of the average utilities of the time dependent strategies with regard to the rational strategies except in the case where these are conciliatory.

This observation shows that the rational agent doesn't wish to maximize his gain other than to reach a final agreement with his rival and to succeed the negotiation process.


Figure 5. Agreement's rate

### 3.3 Agreement's rate

As presented in Figure 5, the agreement's rate is almost total: all the negotiations' cases succeed independently of the player's strategies.

This result accentuates the rational strategy's end that is to reach final agreement, by taking into consideration, when making decision, the opponent's preferences.


Figure 6. Average round to reach agreement

### 3.4 Average Roundsto reach agreement

We notice according to Figure 6, that the average rounds number to reach agreement, for different strategies are so small that not exceed eight rounds (experiment of rational agent against an aggressive dep. time agent).

This experiment denotes inefficiency shorten trade time independently of competitors' strategies.
This result shows a significant gain in negotiation's spent time for the two players.

## 4. Conclusion

This work presents a solution for the problems of discord and conflicts between competitive rivals in an automated bilateral negotiation. This solution defines a rational strategy based on games theory to carry off successful future players' interactions and to guarantee final agreement in a reduced time negotiation.

The experimental studies a bilateral negotiation case between a rational agent (a buyer) and a behavioral time dependent agent (a seller). It shows a success of the rational strategy to guarantee mutual agreement between conflicting interests' players and a significant reduced negotiation's time to reach final compromise.

But the rational strategy doesn't guarantee an optimal gain for the rational player rather than for his opponent.

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