# A Cooperative Negotiation Model in a Hostile Dynamic World

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## Abstract

*In multi-agent setting agent teams often encounter conflicts in agents' plans and actions. This paper presents a cooperative negotiation model (ABCON) that allows agents in a team to appropriately negotiate various options in a hostile and dynamic fire world. It shows that negotiations explore the attitudes and behaviors that help agents to manage conflict constructively. It says that cooperative negotiation is guided by the agents' dynamic assessment of alternative actions given the different scenario conditions.*

## 1. Introduction

The negotiation theory has received a great deal of attention from the multi-agent system community [4][5][7][8]. Negotiation is the process of searching for an agreement that satisfies various parties. It is an ongoing process that occurs against a backdrop of continuing relationships and events. Negotiations are like a chess match during conflicts in cooperative environment; have a strategy; anticipate how the other will respond; how important is the issue and situation for you. Thus a negotiation usually involves a number of steps including the exchange of proposals and counter proposals. During the negotiation process an agreement may be reached through the facilitation of the achievement of cooperation among entities such as individuals, groups or teams.

This paper presents a model for negotiation with specific application to a fire world. We say that based on the beliefs that arise in the process of conflict resolution in the hostile dynamic environment, we formulate specific *attitudes* about the strategies we will use in the negotiation. These may be quite general (e.g. Plan to use a cooperative approach) or quite specific (eg. Use a specific negotiating tactic.). Finally *attitudes* are translated into behavior. These behaviors in turn elicit some response from the other agent and the process goes on. Our objective is the development of a simulation environment of a real world situation, in which conflicts can be resolved amicably through negotiations. We aim to design cooperative agents, which can survive in a hostile dynamic world and solve problems with other similar agents inhabiting the same world. These agents will be capable of interacting with each other both individually and collectively. In addition, they will be capable of deriving plans and negotiating over the resources in order to achieve a common goal.

Negotiation mechanism depends heavily on the specific characteristics of the scenarios under consideration. In hostile dynamic domain the passage of time during the negotiation is the most important consideration. Also negotiations as a way of reaching mutual benefit are a costly and time-consuming process and, consequently, it may increase the overhead of cooperation and coordination. In the presence of time constraints, planning and negotiation time [9] should be taken into consideration. Kraus et al. [6] analyzed a number of problems related to resource allocation and task distribution among self-motivated, rational and autonomous agents while involved in multi-agent negotiation under time constraints. Their approach crucially tackle the issue of instantaneous outcomes: given that the negotiation cost is taken into consideration, the negotiation should end as quickly as possible, possibly in the first round.

## 2. A Framework for Cooperative Negotiation

The negotiation process facilitates the achievement of cooperation among different agents. The cooperation among agents succeeds only when participating agents are enthusiastically unified in

pursuit of a common objective rather than individual agendas. The negotiation is a higher-level discourse function involving distinct acts to reach a group consensus. We claim that cooperation among agents is achieved only if the agents have a *collective attitude* towards cooperative goal as well as towards cooperative plan.

There are two views toward negotiation: focus on a particular task, or focus on a decision that may involve consideration of multiple alternative tasks. In this paper, a key aspect of collaboration is negotiating about alternative ways to achieve goals. To support such negotiation, we have extended our representation so that task models support reasoning about alternative, mutually exclusive courses of action (recipes) for achieving tasks, and we have added mechanisms for evaluating the relative strengths and weaknesses of different alternatives. We use heuristic approach to resolve our conflicts in a team. Such methods acknowledge that there is decision-making involved with computation and so seek to search the negotiation space in a non-exhaustive fashion. The key advantages of the heuristic approach are that it is based on realistic assumptions and can use different alternate options.

### 2.1 Definition of Attitude

Attitude is a *learned predisposition to respond in a consistently favourable or unfavourable manner with respect to a given object* [3]. But we define attitude as *a predisposition to respond consistently in favourable or unfavourable manner with respect to a given object.* In other words, the attitude is a preparation in advance of the actual response, constitutes an important determinant of the ensuing behaviour. However this definition seems too abstract for computational purposes. In AI, the fundamental notions to generate the desirable behaviours of the agents often include goals, beliefs, intentions, and commitments. Goal is a subset of states, and belief is a proposition that is held as true by an agent. Bratman [1] addresses the problem of defining the nature of intentions. Crucial to his argument is the subtle distinction between doing something intentionally and intending to do something. The former case might be phrased as deliberately doing an action, while intending to do something means one may not be performing the action in order to achieve it. Cohen and Levesque [2], on the other hand, developed a logic in which intention is defined. They define the notion of individual commitment as *persistent goal*, and an intention is defined to be a commitment to act in a certain mental state of *believing throughout* what he is doing. Thus to provide a definition of attitude that is concrete enough for computational purposes, we model attitude using goals, beliefs, intentions and commitments. From the Fishbein's [3] definition it is clear that when an attitude is adopted, an agent has to exhibit an appropriate behaviour (predisposition means *behave in a particular way*). The exhibited behaviour is based on a number of factors. The most important factor is goal or several goals associated with the object. During problem solving, an agent in order to exhibit behaviour may have to select from one or several goals depending on the nature of the dynamic world.

In a dynamic multiagent world, the behaviour is also based on appropriate commitment of the agent to all unexpected situations in the world including state changes, failures, and other agents' mental and physical behaviours. An agent intending to achieve a goal must first commit itself to the goal by assigning the necessary resources, and then carry out the commitment when the appropriate opportune comes. Second, if the agent is committed to executing its action, it needs to know how weak or strong the commitment is. If the commitment is week, the agent may not want to expend too much of its resources in achieving the execution. The agent thus needs to know the degree of its commitment towards the action. This degree of commitment quantifies the agent's *attitude* towards the action execution. For example, if the agent considers the action execution to be *higher importance* (an attitude towards the action), then it may choose to execute the action with greater degree of commitment; otherwise, the agent may drop the action even when it had failed at the first time. Thus, in our formulation, an agent when it performs an activity, since the activity is more likely that it will not succeed in a dynamic world, agents will adopt a definite attitude towards every activity while performing that activity. The adopted attitude will *guide* the agent in responding to failure situations.

### 2.2 Attitude Based Team Model

We claim that team activity is achieved only if the agents have team as a collective abstract attitude. From collective attitudes, agents derive individual attitudes that are then used to guide their behaviors to achieve the team activity. We consider two agent team in this paper i.e. $A_1$ and $A_2$. So the collective attitude of the agent $A_1$ and $A_2$ towards the collection team is

represented as $Team_{A1A2}(A_1, A_2)$. But from $A_1$'s viewpoint, team is an attitude that it is holding towards the collection $(A_1, A_2)$ and can be denoted as $Team_{A1}(A_1, A_2)$. Similarly from $A_2$'s viewpoint, its attitude can be denoted as $Team_{A2}(A_1, A_2)$. But the collective attitude $Team_{A1\ A2}$ $(A_1, A_2)$ is decomposed into the individual attitudes only when both the agents mutually believe that they are in the team. In order to establish mutual belief between the agents, the agents have to commit to the team activity by saying so. Besides mutual belief, we model a team using a set of four attributes i.e. team definition ($DEF^T$), team methods ($M^T$), team rule base ($R^T$) and team responsibility ($RESP^T$). Thus $Team_{Ai}(A_1,A_2)$, the abstract attitude of a team agent can be divided into two components (i) attitude towards team definition ($DEF^T$), team methods ($M^T$), team rule base ($R^T$), mutual belief ($MB^T$) and team responsibility ($RESP^T$) (ii) behaviors towards the components of team structure i.e. towards that team definition ($DEF^T$), team methods ($M^T$), team rule base ($R^T$), mutual belief ($MB^T$) and team responsibility ($RESP^T$). The overall attitude towards the team attributes is further divided into the attitudes towards each component using the same attitude decomposition technique described above.

### 2.3 Attitude Based Cooperative Negotiations (ABCON)

Figure 1 presents the overall ABCON negotiation process. The ABCON has three steps i.e. Opening State, Negotiation State, Closing State.

1. Opening State:
   (a) Team $_{A1A2}(A_1,A_2)$ detects a conflict.
   (b) Team believes that it can resolve the conflict
   (c) Else team withdraw the negotiation process.
2. Negotiation state:
   (a) For time less than deadline $t_{max}$, any member in the team may generate proposal to resolve conflict.
   (b) Team's responsibility attribute evaluate the proposal
   (c) If no conflict found within deadline, accept the proposal and go to step 3
   (d) Else if proposal found conflict, continue negotiation through counter-offer.
3. Closing state:
   (a) If suggested proposal accepted terminate the negotiation process.
   (b) Else if conflict found unachievable, irrelevant or the deadline to resolve the conflict is passed, then terminate the negotiation state.

**Figure 1: Stages in ABCON**

We say that, when agents are in team, they should also have appropriate *attitudes* towards *individuals, groups, and society, as well as the team.* Thus when a team of agents undertake a problem, an attitude prescribes each member to perform its part precisely till the problem is solved and the team is dissolved. However, while doing the team activity in the dynamic environment, it is inadequate for the agent to commit to the team activity only. The team agents are autonomous participants that perform specialised functions within a social setting. Thus besides team tasks concerning with the operation of the entire team, we need that the agents to perform activities specific to non-global subtasks. Striving towards a team goal, however, does not imply that every action by every agent need to be team action, since conflict at a local level may occur without compromising the global goals. The conflicts in a team can be due to *autonomy of agents, group-work* and *social obligations.* In this context, social conventions and individual behaviors provide general guidelines which agents can follow. By adopting a convention, every agent knows what is expected of it, and of every other agent, as a part of collective working towards the goal, and implicitly knows that every other agent has a similar set of expectations. Thus besides doing team activity, the team agent also has to do social actions, group work and individual actions. If the *team attitude* of agents is *high* (high degree of commitment), the agents in team follow the team plan or go according to the team agenda. If the attitude of agents in team is *medium,* agents in team may or may not follow the team guidelines. Instead they may follow group, society or individual plans depending on the *attitude* of agents against each entity. If the attitude of agents in team is *low,* agents in team will not at all follow the team plan. A heuristic model to evaluate the proposal given to one team agent to another team agent is given in figure 2.

Another important factor effecting the negotiations in a hostile dynamic world is a deadline $t_{max}$ set by the team to conclude its negotiation for the problem. In case of conflicts in team, the agents follow an

alternating sequential protocol, which has five different stages i.e. *offer, counter-offer, accept, decline* and *withdraw.* An *offer* is a proposal made by the agent to the other, *counter-offer* is a proposal from an agent in response to proposal it received, *accept* is to accept a proposed offer, *decline* is to reject the previously accepted offer and *withdraw* is to terminate the negotiation.

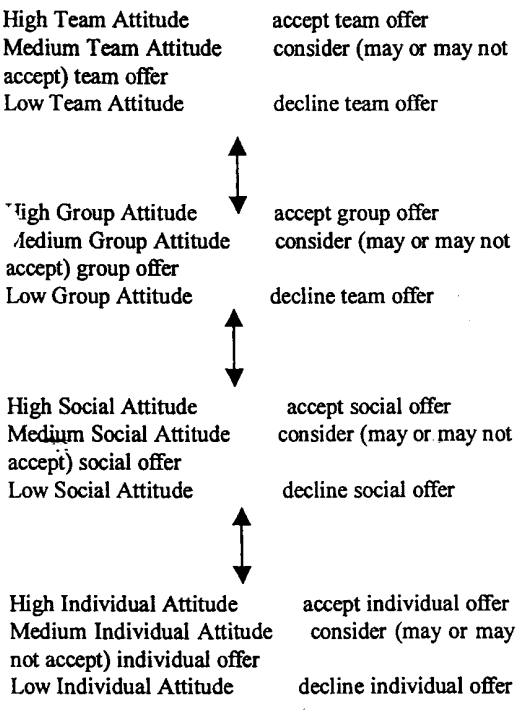


**Figure 2: A Heuristic model for Proposal Evaluation**

## 3. A Fire World

We have implemented our formalization on a simulation of fire world *FFWorld* using a virtual research campus. *FFWorld* is a dynamic, distributed, interactive, simulated fire environment where agents are working together to solve problems, for example, rescuing victims and extinguishing fire. In a world such as this, no agent can have full knowledge of the whole world. Humans and animals in the fire world are modeled as autonomous and heterogeneous agents. While the animals run away from fire instinctively, the fire fighters can tackle and extinguish fire and the victims escape from fire in an intelligent fashion. An agent responds to fire at different levels. At the lower level, the agent burns like any object, such as chair. At the higher level, the agent reacts to fire by quickly performing actions, generating goals and achieving goals through plan execution.

This world contains all the significant features of a dynamic environment and thus serves as a suitable domain for our negotiating team agents. Agents operating in the domain face a high level of uncertainty caused by the fire. Agents in the fire domain do not face the real time constraints as in other domains, where certain tasks have to be finished within the certain time. However, because of the hostile nature of the fire, there is strong motivation for an agent to complete a given goal as soon as possible. There are three main objectives for intelligent agents in the world during the event of fire: self-survival, saving objects including lives of animals and other agents and put-off fire. Because of the hostile settings of the domain, there exist a lot of challenging situations where agents do the team activities. Whenever there is fire, the basic team behavior is exhibited by the fire fighters. The fire fighters perform all the tasks necessary to control an emergency scene. The problem solving activities of the fire fighters are putting out fire, rescuing victims and saving property. Apart from these primary activities there are a number of sub tasks eg. run towards the exit, move the objects out of the room, remove obstacles, and to prevent the spread of fire. Thus the fire world we consider is sufficiently complex to bring about the challenges involved in the problem solving in a typical multiagent world.

## 4. Evaluation

The key evaluation criterion for the overall performance of the team in any environment is that agents must successfully accomplish their tasks within their given environments, both efficiently and accurately. We have done several experiments for fire fighting in *FFWorld* domain to verify our ideas about the cooperative negotiation model. To assess the utility of our model a series of experiments were undertaken. The motivation behind doing these experiments is to determine the advantages and disadvantages of our attitude based cooperative negotiation model. The agents in a team react to the changes in the world states by generating and achieving new goals. Meanwhile, old goals and plans are constantly being monitored and re-structured if necessary. The attitudes are mainly concerned with how to re-organise plans

and goals due to situational changes. Whenever there is a new goal because of the changes in the world, one or more attitudes are usually created along with the team goal. The experiments have concentrated on evaluating the performance of attitude based team in case of unexpected events.

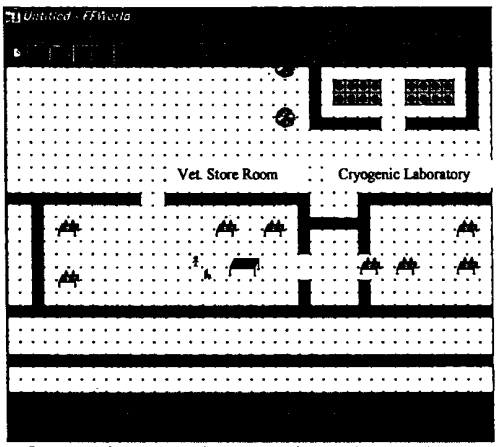


**Figure 3: A Section of FFWorld Showing the Entrance of the Cryogenic Laboratory Blocked by a Table**

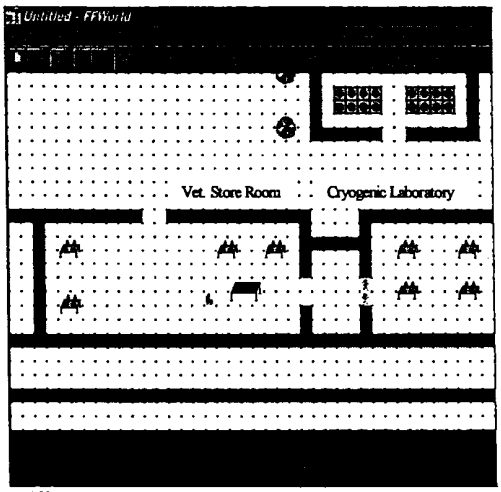


**Figure 4: A Section of FFWorld Showing the Entrance of the Cryogenic Laboratory Blocked by two agents**

When a problem occurs, the attitude model stipulates a new set of behaviours for the team agents. The team agents with attitude respond to changes in the world by adopting a set of attitudes towards these changes. We carried out different types of experiments to investigate the problem solving behaviour of the team agents during team action and to analyse their coherence in hostile dynamic environments. These sets of experiments demonstrate the significance of employing attitudes when team agents have to deal with individual, group, social and team goals in a changing world. A problem for a multiagent system is how it can maintain global coherence(how well a system behaves as a unit) without explicit global control. In this case, the agents must be able on their own to determine goals they share with other agents, determine common tasks, avoid unnecessary conflicts, and pool knowledge. Since the overall goal of fire-fighting teams is to put out fire, it is also interesting and informative to note that how the team performs against a wide range of unseen adversaries and how it can operate in a dynamic, hostile environment.

In this experiment, we have tried to find the probability of success in case of three types of teams (i) both agents in the team having *high* attitude towards team- $T_{high}$ (ii) both agents in the team having *medium* attitude –$T_{medium}$ (iii) agents in the team having *low* attitude –$T_{low}$. The performance of three types of team agents is measured in terms of the rate of change of world and time taken to complete the task.

The *high* attitude based team $T_{high}$ performs better than the *low* attitude based team $T_{low}$, because attitude based agents can easily detect problems and can develop commitments accordingly. The team $T_{high}$ performs better than the team $T_{medium}$ and $T_{low}$, because the agent with *high* attitude can better guide the team to react to unforeseen adversaries. In case of *low* attitude based team $T_{low}$, the agents would not be able to respond to the changes in the world. They will not be able to detect the safe and unsafe conditions of the world and not able to resolve conflicts when they have to coordinate with other agents to use some common resources.

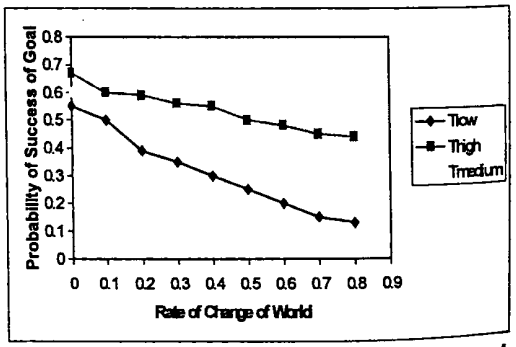


**Figure 5: Probability of Success of Team Goal for the Teams $T_{high}$, $T_{medium}$ and $T_{low}$.**

Figure 5 shows the graph of the experiment measuring the probability of success of goal when the state of the world is changing rapidly. The x-axis of the graph shows the rate of change of the world, while the y-axis represents the probability of success of goal. We measure the rate of change of world in terms of the pace with which the fire spreads out. We observe more severe the situation is (from small fire to large fire), the more efforts the team spends in achieving the same goal (put out the fire). In the meantime, the chances of plan failures increase as the fire world becomes more hostile. This is understandable since medium and large fire creates more difficulties, and poses more challenges for team's planning and plans execution. We note that when the fire is small, the team plan seems to do well, because there are less chances of plan failure. So the number of rules fired is also less. We also found that probability of success of goal in case of high attitude based teams are more, while in case of low attitude based team is less. Similarly, the less attitude based agents will not be able to handle the blockage of the entrance of the room by the agent or by an object (table or chair). There are greater chances of removing the blockage at the entrance in case of attitude based agents. In our experiment, while going to the Cryogenic Lab. the team of fire-fighters find that entrance to the lab. is blocked by the table (figure 3). The team agents responsibility attribute generates social and group attitudes like *help* and *full-coordination*. The team goal generator will insert a new goal $G_{move\text{-}the\text{-}table}$ into the time line. With the insertion of this new goal, there are greater chances of the team agents achieving the main goal i.e. put out fire. Because the new attitudes adopted will help the team agents to move the table to a safe place. Similarly, if one agent is blocking the exit (figure 4), the another agent have to wait for some time. The team agents' attitude generator will generate social attitudes like *wait*. Then the team goal generator will insert a new goal ($G_{wait}$) into the time line depicting the team's social behaviour. These results show that pure interest in team is not a good basis for cooperation. Participation in team problem solving requires some element of compromise i.e. team interests need to be tempered with the consideration for the individuals, groups and society. The cooperative negotiation model helps agents to resolve conflicts due to individual goals, group goals and social goals and generate appropriate solutions to the local problems of the team agents with the help of various attitudes. Whenever a problem occurs in the fire world, the team attitude model stipulates that a new course of action should be devised. The unexpected events in the fire world cause the team plan violation and distract the agents from its intended commitments. In order to simulate the team plan violation, varying numbers of unexpected tasks were assigned to the team during the lifetime of the team action. The agent acting as an individual, group and social agent could solve all these additional tasks. We observe that the chances of plan failures increase, as the world becomes more hostile. This is understandable since large fire creates more difficulties, and poses more challenges for team's planning and plan execution. We note that when the fire is small, the team plan seems to do well, because there are less chances of plan failure.

## 5. Conclusions

This paper has developed a heuristic cooperative model for managing negotiations in a hostile dynamic world. Negotiation is guided by the agent's dynamic assessment of alternative actions given the current scenario conditions, with the aim of facilitating the agents in a team to complete their tasks as quickly as possible. Our solution provides a means of maximizing the predictability of the agents and the team as a whole. The idea is powerful in that it provides ideas about cooperative scheduling and planning as well as collision/conflict avoidance. Its richness presents numerous possibilities for studying different patterns of individual, group and social behaviour.

## 6. References

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