DIPLOMAT, An Agent in a Multi Agent Environment:
An Overview
by

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Abstract:

Diplomacy is a board game, played by seven players. Playing involves a certain amount of technical skills as in other board games, but the capacity to negotiate, explain, convince, promise, keep promises or not keep them, is an essential ingredient in good play. A program for playing Diplomacy (named Diplomat) is described. It is very different from programs that play two-person zero-sum board games (such as chess or checkers) since it must act in an uncertain environment, it must decide on intermediate goals and explain those to potential allies, or hide those from them. Diplomat is able to make proposals to other powers and may also receive proposals and answer them. In case a player suggests a plan, Diplomat must evaluate it and react accordingly. It must also evaluate the relations between the other players in order to detect potentially dangerous coalitions. Diplomat uses a set of domain specific heuristics. The experience shows that Diplomat plays in a way that is hard to differentiate from play by humans.

1. Introduction

Research in artificial intelligence has focused for many years on the problems of a single intelligent agent. This agent, usually operating in a relatively static domain, was designed to plan, navigate, or solve problems under certain simplifying assumptions, the most notable of which was the absence of other intelligent entities. This is becoming less and less true since the presence of multiple agents is unavoidable in the real world. People planning actions must take into account the potential actions of others which might be a help or a hindrance to their own activities. In order to reason about other people's actions and to influence those actions, a person must be able to negotiate with the others and to try to model their beliefs and desires.

A system that acts as an intelligent agent in a multi-agent environment will be described in this paper. In the multi-agent environment, each agent has its own set of desires and goals. Naturally, while conflicts among agents exist, there is still room for cooperation between them. Our system evaluates different long range plans, chooses between them and makes suitable changes as circumstances change or as more information is gathered. The system must select its plans after negotiating with the other agents. During this negotiation the system has to offer suggestions, receive offers from other agents and understand them and it has to save information about the other agents and about the environment. Information gathering is made harder by the fact that agents do not have to be honest: they may promise and not fulfill their promises or lie about what they know of other agents.

Programs capable of acting in the multi-agent environment described above could be helpful in some everyday situations. An automated secretary, for example, may be required to coordinate a schedule with another automated (or human) secretary, while properly representing the desires of its owner. The full capability to negotiate, to compromise and promise, would be highly desirable in this type of encounter.

2. The Diplomacy Game

Since the general problem of acting in a multi-agent environment is very complicated, we decided to concentrate on a specific example of such an environment and to analyze the behavior of an intelligent agent there. The environment we decided to concentrate on is a game, named Diplomacy, marketed by Avalon Hill, Company. Diplomacy is a board game played on a map of Europe during the years just prior to World War I. Each player plays one of seven European powers: Austria-Hungary, England, France, Germany, Italy, Russia and Turkey and seeks control over Europe. The moves of the game are figured as two moves each year: a Spring move and a Fall move, beginning in year 1901. After negotiation, each player privately writes down on paper the moves for all of his units. Chance plays no part. To be a good player one needs some technical skills in moving military units on the board according to the reasonable but complex rules of the game, but above all one needs the ability to communicate and negotiate with the other players, make agreements with the others and possibly decide to break these agreements, since the rules do not bind a player to anything that he says. Deciding whom to trust as situations arise is part of the game. This ability to negotiate is essential since certain moves require tight cooperation between different allied powers (the units of a power may help the moves of another power). Such cooperation is much closer than in other similar games, such as Risk, where cooperation is only non-interference. Details of the rules of the Diplomacy game may be found in [1]. Diplomacy is really a *multi*-agent environment (not simply a two-agent) since the players cannot be divided into two competing groups, since alliances may change.

A program able to take part in a game of Diplomacy has been developed and will be referred to as Diplomat. Diplomat is implemented in Ylisp [10] (a dialect of Franz-Lisp) on a Vax 11/785. The current version is the product of two years' work by three programmers.

3. Comparison with Other Work

Diplomacy is very different from other games that were considered in the artificial intelligence community. For example, one may compare Diplomacy with Chess. The best programs that play Chess use search methods. Those methods are not applicable to Diplomacy for several reasons.

First of all, in Diplomacy, the number of possible moves is much larger since in every move every player gives orders to all of his units simultaneously. There are usually 34 units on the board and the average number of possible orders for each unit is 8, so the average number of possible moves in a season in Diplomacy is 34^8. Note that in chess the average number of possible moves for each

player is 80 and for a round, 80^2. In fact, since the basic actions of a player involve negotiations, every possible step in a negotiation should be considered a basic move. The number of such possible moves is overwhelming.

But the problem is much deeper. To use search for game-playing, one needs a good evaluation function. In a game, such as Diplomacy, in which some moves may have only long-range purposes (e.g. to help an ally in order to get something from him in return later on), it is very difficult to find such a satisfactory evaluation function. In Diplomacy, such a function would have to include the state of mind of the other players, but this is very hard to quantify. Indeed, the uncertainty of each player regarding the state of mind of other players (including their evaluation of the value of possible intermediate goals) and the consequences of his actions on their states of mind makes Diplomacy, in fact, a repeated game of incomplete information (see [3]). As Shubik says ([12]):"A major difficulty in applying game theory to the study of bargaining or negotiation is that the theory is not designed to deal with words and gestures-especially when they are deliberately ambiguous moves".

Therefore, Diplomat uses searching only to look for plans that could be proposed to a partner in a negotiation. For all those reasons our methods are mainly heuristic and knowledge-oriented instead of search-oriented. This approach is similar to the approach of the chess program PARADISE, written by D. Wilkins [14].

There is a Diplomacy program, "Computer Diplomacy", marketed by Microcomputer Games, a division of Avalon Hill Co., that runs on the IBM-PC. It plays but cannot negotiate. It can only order its units around the board according to the rules. Since Diplomacy is mainly a game of negotiations, the interest of this program is limited. The tactical skills displayed by this program are also of limited value, and our strategic procedure (without diplomacy) beat this program in all of the games they played against each other.

In prior works, [2],[4],[5],[6] and [7], cooperative multi-agent systems were developed. For example, the TEAMWORK 2 system, developed by Ambros-Ingerson, Doran, Steel, and Trayner, [2] is a cooperating multi-agent team. The approach of Ambros-Ingerson et al. is different from ours. They want to investigate team behavior and concentrate on overall system problems such as: ways of handling communication between the agents and the scheduler. In our work, in addition to developing the game environment, we concentrated on investigating the behavior of a single agent in a more complicated environment. Our agents are competing, but they may cooperate if they feel they can benefit from such cooperation. They may also betray and try to fool other agents. In TEAMWORK 2 the agents are all autonomous and thus all may be engaged in separate tasks having no connection with each other. Alternatively, an actor may use other actors to assist him in the completion of its task, but no negotiating is used in order to achieve it.

A formal framework that models communication and promises in multi agents interaction has been developed in the work of Rosenschein, Genesereth and Ginsberg [15], [16], [8], but their models are far from being able to handle the complexity and range of problems found in our system. Although, our system concentrates on a specific example, we think that the methods we developed and the ideas we used, can be used while developing other systems working in similar environments.

4. The Game Environment

In order for Diplomat to be able to play with other human players or other computerized players, we have developed a computerized manager for Diplomacy and ways of communicating between players that will suit both human players and computerized ones. Its main task is to act as a postmaster for all players during the periods of negotiations. Players do not know the real identity of the other players and only the postmaster knows which power is played by Diplomat.

The postmaster also provides equal conditions to the human players and the computerized ones by restricting the language in which negotiations may be held. Usually Diplomacy negotiations are pursued in natural language, but since natural language understanding is beyond the scope of our project, all messages are written in a limited language that was developed for communication between Diplomacy players and will be referred to as diplomacy language. This language has to be rich enough to enable the players to negotiate, but a computerized player has to be able to analyze the messages in this language easily. The manager forces the human players to send their messages in the diplomacy language and helps them use it. The computerized players use an internal representation of the language in the form of tree structures. The postmaster translates from one representation into another.

There are four kinds of messages: declarations, questions, suggestions and answers. Declarations are used to convey information (correct or incorrect) and they generally do not require an answer.

A declarative sentence is used to make the receiver believe in the content of the sentence. When Diplomat receives a declarative message, it compares its content with what it already thinks and, taking into account also the confidence it has in the sender, decides whether to believe in the messages, updates its data base accordingly and considers whether to pass the information on to another player. Diplomat sends declarative sentences when it wants to convince another player to accept its suggestions, to help its allies or to mislead its enemies.

Questions are essentially declarations in the interrogative form and they are used to get information and to ask for clarifications concerning a previous suggestion. They require an answer. Diplomat asks questions mainly when it needs more details in order to decide whether or not to accept a suggestion. After receiving a question, Diplomat decides whether or not to answer this question. Its answers to questions are not always honest.

Suggestions are used as preliminary steps towards agreements. They focus the negotiations on specific plans. These plans may be detailed or only general sketches. They require an answer or a counter-suggestion. Diplomat sends a suggestion when it wants to sign an agreement with another player. This suggestion is based on a strategy that has been chosen after a search for possible strategies. When Diplomat receives a suggestion, it evaluates its worth for itself, decides whether or not to accept it, and what answer it should send the other party.

Answers are used to finalize agreements after a suggestion, to answer questions or to wait for another suggestion from the other party. Answers may be positive or negative, and they contain a level of strength. Diplomat sends a positive answer when it wants to accept a suggestion regardless of whether or not it plans to keep the agreement. A 'weak' positive answer is sent when the ideas in the suggestion seems reasonable to him and it wants to

continue the negotiations. A negative answer will be sent by Diplomat when it does not want to accept the suggestion and it does not care if the other party knows this. After receiving a weak positive answer, Diplomat tries to convince the other party that its own suggestion is a good one, or it suggests something else. A negative answer puts an end to this negotiation, and a positive one ends it successfully. More details about Diplomat's behavior during the diplomacy period will be described in the following chapters.

Some examples of messages:

<MESSAGE 1 FROM Russia TO Turkey> :

I would like to suggest to you a Cooperation Agreement between Russia and Turkey against Austria from now on; The Terms:
- Russia and Turkey will not enter BLA any time,
- Russia and Turkey will not enter ALB any time,
- Russia will attack RUM from the coast of SEV now,
- Turkey will attack SER now -

END OF MESSAGE.

<MESSAGE 6 FROM Turkey TO Russia> :

In answer to message # 31: Yes,absolutely.

END OF MESSAGE.

(More examples of messages written in the Diplomacy language may be found in Appendix B in [9]) From now on we will concentrate on the system, Diplomat, which is able to take a part in a Diplomacy game as one of the players.

5. General Description of Diplomat

After observing many Diplomacy games and analyzing the behavior of the players in those games, we decided on a framework for the behavior of Diplomat, our program that plays Diplomacy. In this framework some values, corresponding to "personality" traits, may be easily varied from game to game. This variability allows a search for the best values and also allows Diplomat to change "personality" from game to game. According to some authors this versatility is characteristic of good play (see for example Walker [13]). The introduction of personality traits in game playing programs has been studied in [11].

The behavior of Diplomat is as follows. At the beginning of every season Diplomat has an updated data base, that will be described below, that contains information about Diplomat's beliefs about the powers, the relations between them and its valid agreements. For Diplomat, an agreement is valid if Diplomat and its partner have both confirmed it, irrespective of whether Diplomat intends to keep it or not. Agreements may be detailed and include the promise to perform specific moves on the board and the promise not to perform some other moves, but they may also be more general and include promises of non-aggression, an alliance against a named third party or information exchanges.

When negotiating, Diplomat distinguishes between allies (powers with which Diplomat has a valid agreement) and others. In case there exists an agreement between Diplomat and another party, Diplomat will do the following:
1) look for reasonable strategies that fulfill the existing agreement and evaluate the expected profits from those strategies, for itself and for the other party. The expected profit is quantified by three numbers: a minimum profit, a maximum profit and an average profit. These numbers are computed by confronting Diplomat's strategy with possible strategies for the opponents. The value of a position is estimated by adding the values of the spaces controlled. Random draws are used in Diplomat's search for strategies, therefore Diplomat will never play twice in the same way. A non deterministic behavior is an important issue for success in a Diplomacy game.

2) Diplomat chooses the best of those strategies according to its "personality". Its "personality traits" define the respective weights to be given to each of the three profits.

3) Diplomat must choose between three options: to fulfill the agreement, to try and change it or to break it. In order to decide, it looks for reasonable strategies that break the agreement or change it, the same way it found strategies which fulfill the agreement. (1 and 2 above). Its willingness to break the agreement or to change it increases with the size of the difference between the expected profits from the strategies chosen in step three and the the expected profits from the strategy which fulfills the agreement chosen in steps one and two. It decides to fulfill the agreement if this difference is smaller then a threshold which is determined as an increasing function of Diplomat's loyalty trait. It also tries to measure the willingness of the other party to keep the agreement. Diplomat's willingness to fulfill the agreement increases accordingly.

In case the program decides to break an agreement, it still has to decide whether to pretend to keep the agreement or to tell the other party. Its decision is influenced by its loyalty traits. If Diplomat decides on betrayal it will find a strategy to negotiate so as not to raise the suspicions of the other party.

If Diplomat and the other party do not have a previous agreement, Diplomat will try to find a common enemy, to search for a good strategy and to decide whether to start negotiations or not.

After finding a full plan of action that is profitable and can be a basis for negotiation with another party, Diplomat has to decide which parts from this plan to reveal its potential ally, and in how much detail. When Diplomat requests help in a specific way, such as support, convoy or cutting support, from his ally or offers to give such help, he must tell him the exact details. But some details of the full plan are not directly connected to the proposed cooperation: some are connected to other actions of Diplomat, some with actions of the potential ally not directly affecting Diplomat. The question is whether to reveal all of Diplomat's orders and whether to give its ally advice concerning moves not directly connected with Diplomat or not. Our answer depends on the balance of forces between Diplomat, its ally and their common enemies. Diplomat's willingness to give advice to its ally increases when the ally is weak relatively to their common enemies, since Diplomat is keener to help a weak ally to prepare a bright plan than to help a strong ally get even stronger. Diplomat may also receive proposals from other powers and answer them. In case a player suggests a plan, Diplomat must evaluate it and react accordingly.

So, during the negotiations Diplomat exchanges messages with the other powers. After receiving a message it tries to understand what the other power really means. First it tries to find out whether the message should be considered an answer, a suggestion, a declaration or a question. This is not always easy since players may sometimes use, for example, a declaration sentence for a suggestion.

When Diplomat receives a message where details are missing, Diplomat tries to fill the gaps, when possible, like a human player.

For example, if the other party suggests some help for defending Diplomat's space, without mentioning how, Diplomat checks the ways it can be done. If there is only one possible way to do it, Diplomat won't ask more questions. Otherwise, it evaluates the open possibilities and decides whether to ask for more details, to suggest a suggestion or maybe to send a positive or a negative answer.

One of the main problems of Diplomat, when receiving an offer or a positive answer to one of Diplomat's suggestions is whether to believe in its content or not. This decision is taken on the basis of the estimated loyalty of the power that sent the message, and the profit the other player can gain from keeping its promises.

When receiving a proposal Diplomat also has to decide if to receive the proposal or not, and this is done by comparing with other possibilities, the state of the negotiations and the 'personality traits' of Diplomat.

At the end of every season Diplomat must write its move orders, taking into consideration the agreements it made and using the strategic plans it found during the negotiations period.

After each move Diplomat tries to estimate the relations between the powers and updates its data base. It also checks whether its allies kept their promises and updates its confidence and its table of current agreements.

The details of the implementation of Diplomat will be described in the following sections.

6. Diplomat's Data Base

Diplomat keeps its view of the game situation in its data bases which includes the following parts: the rules of the game, an archive, the state of the game, an agreements table and information about the powers and their relations.

In the archive Diplomat keeps the messages and the moves of the previous seasons.

The state of the game includes the units' positions, the supply centers' owners and the current date (season and year). This is updated after each season.

The agreements table contains the information about all of the agreements between Diplomat and the other powers. We limited the agreements to be only between Diplomat and one other power (no three-way agreements) for simplicity. Every entry in the agreements table contains the name of the ally and possibly a list of enemies, the details of the agreement and the strength of that agreement in Diplomat's view. The strength of an agreement measures the expected profits for Diplomat from this agreement, its possible clashes with other agreements Diplomat may have and Diplomat's evaluation of the other party's intentions to keep this agreement. Diplomat's willingness to keep the agreement increases with the growth of the strength parameter. Diplomat may have two contradictory agreements, but before signing such agreements Diplomat decides which of them to keep according to their strength parameters. The agreement table is changed during the diplomacy period, when Diplomat agrees to a suggestion of another party or another party agrees to one of Diplomat's suggestions. It also changes after each move, when Diplomat checks whether the allies (including itself) have kept their promises. After each move, Diplomat also erases from the valid agreements those clauses which are now irrelevant and keeps only those terms that concern the future.

One may only estimate (but not really know) other parts of a situation in the game. A Diplomacy player must, therefore, be able to estimate the relations between the other players, measure the

other players' loyalty and their style of play and perhaps guess how they see the current situation in the game.

Diplomat maintains information encoding its beliefs about every power: the measure of loyalty of this power, its willingness to take risks and if it plays the game in a defensive or an aggressive style, which helps Diplomat guess during the game if that power will attack or defend. Diplomat also keeps such information about itself (referred to above as "personality" traits) that is given to him as parameters at the beginning of the game.

The information about the powers is changed after each move and during the diplomacy period since Diplomat may receive messages concerning the other power's character and behavior. It must decide whether or not to believe in the messages it receives. This decision is taken on the basis of the estimated loyalty of the power that sent the message and whether the facts described in the message fit or do not fit Diplomat's beliefs about the current situation in the game. If Diplomat decides the information should be believed, its belief base is changed accordingly.

Besides the local information about every power, Diplomat also keeps information about the relations between the powers. We decided for simplicity's sake to restrict ourselves to only two kinds of relations between the players: friends (F) and enemies (E). The purpose of this classification is to enable Diplomat to guess the probable coalitions. So for every power Diplomat keeps its beliefs about this power's friends and enemies. It is possible that Diplomat will not be able to decide whether or not two powers are friends or enemies. After each move Diplomat tries to evaluate those relations. It believes that two powers are enemies if they attack one another's units or supply centers and it will believe that they are friends if they gave support to one another or convoyed the other's power units. Its beliefs about the relations between the powers can also be changed during the diplomacy period since Diplomat may receive messages concerning the relations between the powers. It must decide whether to believe those messages according to the above procedure and if so it changes the data base accordingly. If Diplomat uses information that it received from another power to determine relations between two powers, it will associate the name of this power with this relation and will update this power's loyalty measure after verifying or refuting the existence of this relation. Note that even from the move's orders one may only estimate (but not really know) the relations between powers.

We have some ideas about how to make the belief base more general. We can extend the belief base in such a way that for every power Diplomat will maintain a data base, as it does for itself, about how this power sees the game environment. It means that we will be able to say, for example, Diplomat believes that $power_i$ believes that $power_1$ is a friend of $power_2$. This extension may be very useful when Diplomat evaluates possible agreements, but may be very difficult to maintain.

Another possible extension is to add weights to the strength of the belief of Diplomat in a relation between two powers.

7. Diplomat's internal design

In any time during the game Diplomat has different goals to satisfy. It has to find good strategies for different fronts, it has to negotiate with other powers, at the end of the season to write orders, retreats and builds and it must analyze other orders. So, the internal design of Diplomat is built around co-operative multiple goal-process, processes with a particular goal to perform. Every goal-process has its own task and it may use other goals to assist it

in the completion of its tasks: by asking for information or delegating some of its work to other goal-processes. There may be conflicts between the goal-processes. Diplomat has a controller that manages its internal behavior and communicates with the outside world: it receives the messages from the other players, through the computerized manager, and it allocates each message to the goal that is most suitable to handle it. Goal-processes may be created by the controller and by other goal-processes. All the parts of a goal-process may be changed by itself and by the controller. The controller chooses the goal-process that will be active according to the priorities of the goal-processes, and may pass internal messages between the goal-processes. Every internal message may be addressed specifically to one of the other goal-processes or to a set of goal-processes described by special pattern.

The structure of each goal-process is as follows:
a) A unique identifying number.
b) The priority of the goal-process. It is used by the controller to determine which goal-process will be active next. The priority is static (fixed at creation time) and it is a function of the type of the goal-process and its parameters. For example, a 'desk' goal-process is more urgent then a 'front' goal-process, since another power may wait for a message that is sent by the 'desk' goal-process.
c) The state of the goal-process which is either **run** or **sleep**. A goal-process sleeps when it waits for an event (message for example), when it has finished fulfilling its task or failed. The controller chooses the next active goal-process from the goal-processes that are in state run.
d) The type of the goal-process: there are different types of goal-processes which perform different tasks:
  Desk- negotiates with another power.
  Front- searches for strategies in a given front.
  Analyze_moves - analyze all the players moves after each season and updates Diplomat's data base.
  Moves - writes Diplomat's moves at the end of each season.
  Retreats_builds - writes Diplomat's retreats and builds when they are needed.
e) The parameters of the goal-process. Each type of goal-processes requires specific parameters.
f) The identifying numbers of the goal-processes this goal-process is especially interested in communicating with. A goal-process usually sends its internal messages to the goal-processes in this list.
g) Mailbox: the controller broadcasts the internal messages among the goal-processes and puts the relevant internal messages in this field.
h) Private storage.

An example of Diplomat's goal-processes is the 'Desk', which negotiates with another power. Such a goal-process plays the role of a department of the Foreign Office charged with coordinating all relations with a specific power. This goal-process is created by the controller, after receiving a first message from another power or by a Front goal-process which found some promising plan to be executed in cooperation with another power. The parameters of this kind of goal-process are the following:
1) The power to negotiate.
2) Possible common enemies to make agreements against.
3) The purpose of the negotiation: to achieve cooperation or to achieve a non-aggression pact.
4) The state of the negotiation: start an agreement, continue an agreement from a previous season, break an agreement without telling your partner or cancel an agreement and tell the other power.
5) A plan that is a basis for negotiation (may be nil).
6) The last message that was received from this power which is put

there by the controller.

A goal-process of type 'Desk' may communicate with Front goal-processes to get strategies and to analyze suggestions from the other party. The body of this goal-process contains Diplomat's previous messages relating to this power from the current season.

8. Conclusions

Diplomat knows how to play Diplomacy, and the experience shows that Diplomat plays in a way that is hard to differentiate from play by humans.In some situations it plays better than the authors. Diplomat has not yet played a sufficient number of games to allow us a meaningful statistical analysis of its performance, and we intend to arrange more games, to analyze them and maybe to improve Diplomat's behavior.

9. Acknowledgements

10. References

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