E-Negotiation Support for Boundary Conflict Resolution

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Abstract

This paper proposes multi-agent e-negotiation support architecture for boundary conflict resolution. We use intelligent agents to act as human assistants during the negotiation task and provide means and resources for making final decisions in case there is a discrepancy in opinions about the decision matter. As an illustration we describe a scenario in marine weather forecasting and discuss how the proposed framework may support forecasters when negotiating agreements toward a consistent forecast policy at the boundary of regional forecasting centres.

Keywords

E-negotiation support, automated negotiation, intelligent agents, boundary conflict resolution, marine forecasting

1. INTRODUCTION

The concept of e-negotiation support has attracted considerable research attention and resulted in a number of applications (Kowalczyk et al, 2003; Kersten, 2002; Goldsmith et al, 1999; Sycara, 1985; Yan et al, 2000; Yen et al, 2000). E-negotiation handles electronic exchange of offers to negotiate an agreement. Most e-negotiation support models are generic and applicable in e-commerce context (Guttman and Maes, 1998; Kersten and Noronha, 1997). Negotiation support models use theories such as game theory, multi-attribute theory or group decision-making as underlying concepts to assist decision-makers in resolving the conflict or achieving agreement. The main advantage in using e-negotiation support systems is that they can support collaboration between decision-makers who are geographically dispersed in space and time.

In this paper, we are interested in negotiation process between two or more decision makers who operate in adjacent or overlapping areas of a problem domain. They hold jurisdiction over their respective Area of Responsibility (AOR), but aim at achieving consistent decision at the boundary. The decision situation we consider is even more complex when it addresses dynamic continuous system as a subject of a decision. This is a typical situation which can occur in applications such as weather forecasting, biological research, healthcare and others. Traditionally this type of decisions requires a lot of time and effort spent in consultations over the telephone or using any other available means for communications.

When two decision makers cannot meet face-to-face to negotiate an agreement, conflict resolution can still be achieved as a result of electronically mediated communication. Systems that support electronic mediation or e-negotiation can be designed to capture the decision makers' "shared mental model" of the conflict situation and to make such model available for reuse or for creating new knowledge. If such models are readily available for real-time access, then decision makers who are currently faced with similar boundary problems may learn from past decisions (e.g., re-use solution to a similar past problem; create new knowledge based on solutions to similar problems). Consequently, the amount of time needed to resolve the boundary problem can be reduced, and quality of boundary decision can be improved. For time-critical boundary problems, it is important that quality decisions are made in timely manner so as to avoid any fatal consequences.

In the following sections, we define the boundary problem that we wish to address. We then describe a sample boundary conflict scenario in marine forecasting to stress the need for e-negotiation support during critical marine weather events. Our initial investigation of boundary problems faced by marine forecasters in Australia motivated our design of web-based multi-agent negotiation support model. We present this model in Section 4.

2. PROBLEM DEFINITION: BOUNDARY CONFLICT RESOLUTION

Negotiations are conducted to resolve contested issues. The resolution is usually the division of those issues in a way that each party gains some benefit. The particular negotiations of interest described in this paper relates to the resolution of contested issues at the jurisdictional boundary that are superimposed on a dynamic and continuous system that does not recognise nor reference the jurisdictional authority.

The contested issues relate to the discontinuity between system parameters at the boundary when these parameters are set independently by each jurisdiction authority. The negotiations are undertaken by decision-makers (*DMs*) to resolve this discontinuity with the objective to synchronize the parameters at the boundary to ensure that the system is seen as continuous across the boundary from the perspective of either jurisdiction. Moreover any adjustment also needs to be consistent with the definition of the system within either jurisdiction or AOR.

An additional feature of such negotiations is the limited timeframe for the negotiations. This constraint is imposed because the jurisdictions set arbitrary deadlines for resolving the boundary discontinuities and the fact that the dynamic system evolves and changes over time thus changing the premise of the negotiations.

One example of such negotiation problem relates to weather forecasting. The structure of the forecasting service in Australia is organised around regional offices that are based on State government geographical boundaries. These regional offices have authority for all forecast products within the State boundaries. The negotiations to resolve forecast discrepancies at jurisdictional boundaries are currently conducted over the telephone, relying on verbal descriptions of the weather system. The time limitation in these negotiations often results in a decision that is not negotiated but imposed through the authority of one of the jurisdictions.

Weather forecasting however has distinct features that make it suitable for e-negotiation. The most prominent feature is that the data that describes the weather system is centrally generated and is uniform for the Australian region. Additionally, the representation of the data is also consistent across all regional offices so there is little scope for ambiguity or misunderstanding of the underlying dynamic weather system. The observational data points are not discrete but are representations of the weather at that geographical location. Since weather is a continuous system, any change to data at a particular location has an impact on all adjacent data points with the effect diminishing with the distance from the source of the change. Thus manipulation of forecast parameters at the boundary needs to take into account the impact of these changes on the predicted weather across the broader forecast area within each jurisdiction. This situation limits the need for negotiations to the relatively small areas at the boundaries of the jurisdiction between regional offices.

3. BOUNDARY CONFLICT RESOLUTION IN MARINE FORECASTING: A SAMPLE SCENARIO

The Bureau of Meteorology (BOM) has seven Regional Forecasting Centres (RFCs) - New South Wales, Northern Territory, South Australia, Tasmania, Queensland, Victoria, and Western Australia. Each RFC is responsible for meteorological forecasting services in their own area. A forecaster uses a lot of domain knowledge in combination with vast amount of electronic information to issue a forecast policy for a wide variety of contexts (e.g. aviation forecasting, marine forecasting, thunderstorm forecasting, etc.) for a wide range of users in his/her *AOR*. A forecast policy constitutes a number of weather elements (wind direction, wind speed, central pressure, temperature, etc) and their relationships that are necessary for producing a variety of weather products (e.g. aviation forecast, marine forecast, thunderstorm forecast, etc). Some of these relationships are empirically known to the forecasters, while others are implicit. The forecast products are currently being produced independently by respective forecasters in their *AOR*, using different forecasting information systems. For example, the Australian Marine Forecasting System (AMFS) is currently used in Tasmania to produce the marine forecasts for Tasmania. The Tropical Cyclone Module (TCM) is used in NSW for predicting future track and intensity of tropical cyclones in NSW.

Despite the availability of supercomputers and decision support tools to help the forecasters produce reliable weather forecast policy, there is still a high degree of uncertainty in the process and outcome of forecast policy formulation because of the amount and quality of subjective judgments exercised by the forecaster in selecting and interpreting the most relevant information. Consequently, the forecast policy formulation and its outcomes differ significantly from forecaster to forecaster, from one forecasting system to another, and between forecasting centres. This leads to high possibility of inconsistency in forecast policy at the boundary.

In order to reduce the inconsistency in forecast policy at the boundary, we propose a system that would allow

- automatic recognition of a potential conflict between forecasts originating within each jurisdiction;

- the ability to share, in a timely manner, forecasts and guidance material especially the graphical representation of the weather system;
- the ability to make the proposed changes and to share such changes between the forecasters;
- the means to identify the impact on the broader weather system of changing boundary conditions;
- the means to articulate mental models of the forecasters including some reasoning and explanation facilities; and
- memory support to store and re-use patterns for resolving future decision situations.

In this section, we focus on marine forecasting and consider a scenario where forecast decision in one *AOR* needs to be consistent with the forecast decision at a neighbour *AOR*. The 1998 Sydney to Hobart Yacht Race (BOM, 2003) is a real-life event that exemplifies the need for RFCs in Sydney, Melbourne and Hobart to collaborate when formulating the marine forecasts in key coastal locations that were adjacent to yacht race course (see Figure 1).

We quote the following background information on the race.

> *"Of the 115 yachts that set sail at 1 pm on 26 December 1998 ..., only 44 reached their destination. The destruction caused by a storm encountered by the fleet triggered a massive search and rescue operation involving numerous personnel from organisations such as the Australian Maritime Safety Authority (AMSA), the Royal Australian Navy (the Navy), the Royal Australian Air Force (RAAF) and Police. Even so, it resulted in the abandonment of several yachts and the death of six people. It was the most disastrous event in the 54 year history of this yachting classic…At about 1 pm on 26 December, meteorologists in both NSW and Victorian RFCs received the latest computer generated prognosis ... which showed the development of a strong low pressure system in Bass Strait. The computer prognosis indicated mean winds of 45 to 55 knots were likely to occur over that area…After consultation between the respective senior forecasters, both offices issued a storm warning. The Victorian warning, issued before 2 pm, covered waters east of Wilson's Promontory and the NSW warning, issued about fifteen minutes later, covered waters south from Merimbula."*
>
> *BOM (2003)*

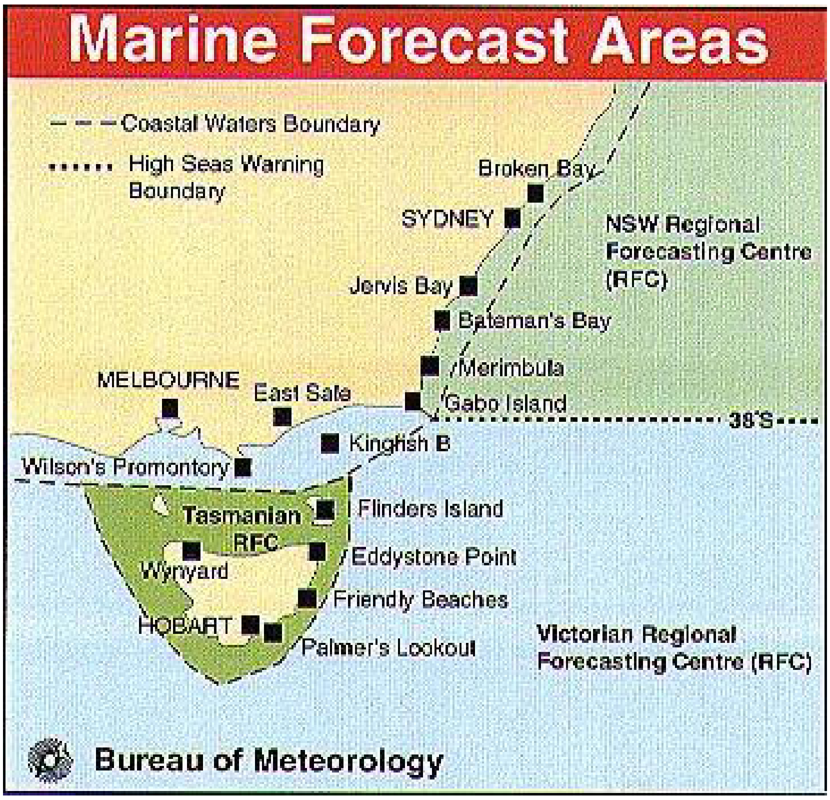

Figure 1: Marine forecast areas during the 1998 Sydney to Hobart Yacht Race (BOM, 2003)

It is evident from the above background information that the Victorian and NSW RFCs have jurisdiction over their respective *AOR*, yet the decision makers (senior forecasters) needed to collaborate to avoid any conflicts in marine forecasts when the fleet crossed the boundary. The boundary decision was *abstract* in nature, in that no actual forecast product at the boundary was produced as a result of collaboration. It should also be noted that the collaboration at such critical situation was conducted via telephone conversations, while the consulting senior forecasters have real-time access to computer prognosis from their respective forecasting information systems and other sources of information (e.g., actual observations recorded by the Navy's race relay ship *Young Endeavour*, coastal radio broadcasts, etc.). In this case no reference material was recorded to store the process of reaching the final decision, so there was no material for reflection and potential learning was lost.

In this paper we propose an e-negotiation support model to support the collaboration among senior forecasters during critical scenarios such as described above. Our view is that consistent decisions at the boundary during such critical situations could help in reducing the number of deaths and costs of damage and improve the quality of products and services of the BOM.

This view is in line with the objectives of Forecast Streamlining Enhancement Project (FSEP) at BOM, which include "addressing the need to achieve consistent decisions at the boundary and the need to collect best practices toward improving quality, quantity, consistency and timeliness of weather products and services" (Dance et al, 2003). FSEP also seeks to establish practical and useful basis for analysing and documenting forecast processes.

4. MULTI-AGENT NEGOTIATION SUPPORT MODEL

Multi-agent technology is a "paradigm for structuring, designing and building systems that require complex interactions between autonomous distributed components" (Kowalczyk et al, 2003). Multi-agent technology has been widely used to support e-negotiation because it allows use of *autonomous agents* to act on behalf of human decision makers who are geographically dispersed, to form a community (called agency or multi-agent system) that allows them to communicate with each other to accomplish a task, to hold some information about the environment and to apply certain actions to effect the environment (Yan et al, 2000). In the e-commerce context, for example, multi-agent technology allows buyers and sellers to effectively trade goods and services over the Internet using *negotiating agents* who act on behalf of the buyers and sellers. Agents possessing intelligent decision making and learning capabilities can bid in auctions, contract negotiations or perform comparison shopping. These agents are also called *intelligent agents* when they perform roles such as information gatherer, information filter, information learner, problem analyser, problem solver, implementation agent, monitoring agent, and negotiating and conflict resolution agent (Bui, 2000).

In our view, multi-agent technology provides a suitable infrastructure for supporting collaboration among marine forecasters, particularly during such critical times when inconsistent forecast policy at the boundary can lead to fatal consequences. Intelligent agents that can track inconsistency in weather elements, alert forecasters of potential danger, perform minimal changes to effect boundary decisions, can perform specific tasks to support automated negotiation, or distributed decision making can provide effective and efficient decision support during time-critical boundary problems.

Figure 2 depicts our proposed multi-agent negotiation support system that will allow decision makers from different jurisdictions, AOR, to meet virtually and negotiate agreements to resolve boundary conflicts. In this model, we assume that a *DM* has jurisdiction over his/her AOR. The decision in each area is acceptable locally, but needs to meet some consistency requirements at the boundary. We propose e-negotiation support model to allow collaboration at both the data and process levels. That is, aside from data exchange and distribution via Internet/Intranet, the details of negotiation process and its outcome can also be documented electronically.

When a *DM* makes decision in which only he/she has jurisdiction, they can initiate a negotiation cycle if there is potential conflict at the boundary. The potential conflict at the boundary will be identified as a problem, and the *DM* needs to articulate such problem publicly by sending problem attributes to a *Problem Attributes Database (PAD)* that is local to the *DM*'s AOR. We assume that there is a way of describing a problem domain as a set of discrete attributes. Even when the system is dynamic, there should be a way of identifying a set of parameters, which describe the state of the system in a detailed enough way. We also assume that problem attributes are defined consistently and understood by all participating decision makers. In the context of marine forecasting, for example, problem attributes relate to weather elements like wind speed, wind direction, swell height, and swell direction. In the context of tropical cyclone forecasting, problem attributes may relate to maximum sustained winds, minimum central pressure, and location of centre of tropical cyclone.

Let $A_i = \{a_{1i}, a_{2i}, \ldots, a_{ni}\}$ be a set of problem attributes identified by the *DM* at the i^{th} area. When inconsistencies are minimal (within a threshold), there is no need to negotiate toward achieving agreement; but if inconsistencies are too high to impact at the boundary and the overall system, then there is a need for disagreeing *DMs* to collaborate and work out a way for resolving the conflict.

From hereon, we refer to $A^* = (a_1^*, a^*_2, \ldots, a^*_n)$ as a *compromise* or *satisficing* solution to the boundary problem, also referred in this paper as the *consistent decision at the boundary*, where $a_i^* = \tilde{a}_i \pm \varepsilon_i$, $\tilde{a}_i$ denotes target value for attribute a_i and ε_i denotes threshold value for a_i. This means that whenever each a_i is within the range $[\tilde{a}_i - \varepsilon_i, \tilde{a}_i + \varepsilon_i]$ then A^* is reached. Otherwise, conflict exists at the boundary and the *DMs* need to be alerted of the need to collaborate toward resolving the conflict.

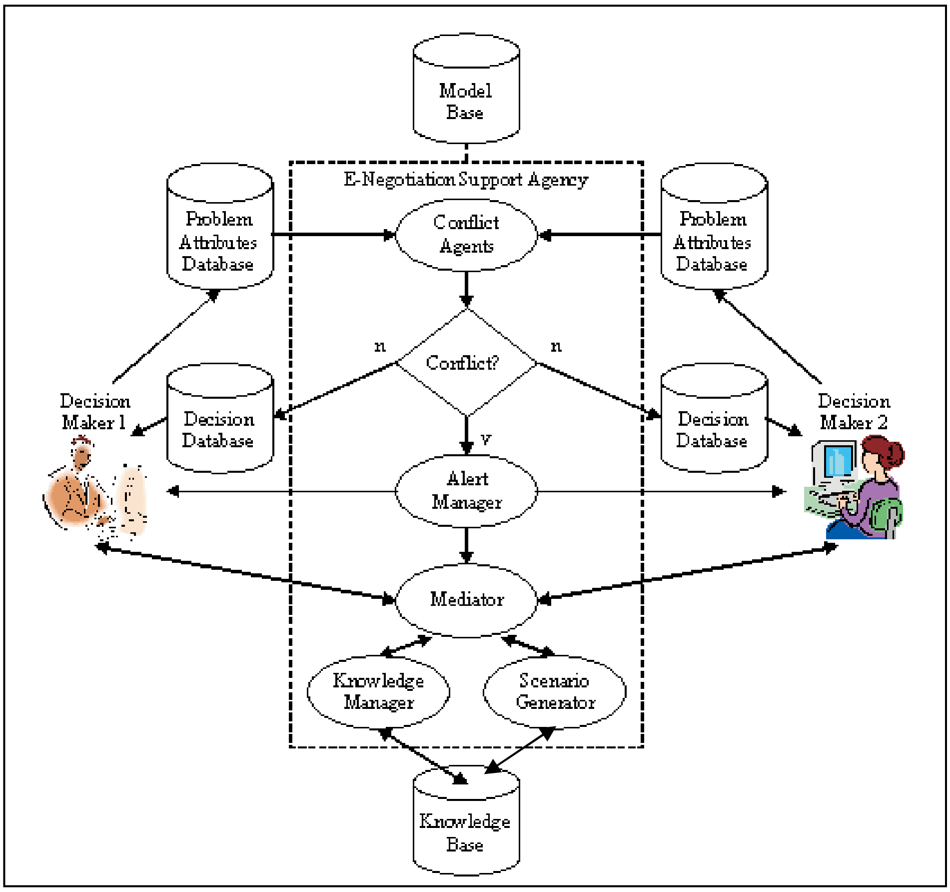

Figure 2: Multi-agent based negotiation support architecture for boundary conflict resolution

We divide the negotiation process into three phases, namely: *pre-negotiation process, negotiation process, and post-negotiation process*. For the pre-negotiation process, we support automated negotiation by employing information-seeking and negotiating agents to collect information about discrepancies in attribute values and to negotiate small changes on behalf of the collaborating agents when inconsistencies are within threshold. In the negotiation process, we use task-based agents to perform specific operations to support the negotiation task between collaborating *DMs*. Post-negotiation process will be supported by an agent that assumes the role of knowledge manager. We discuss in detail these phases and the roles of the agents in the following subsections. All agents are members of the *E-Negotiation Support Agency* as depicted in Figure 2.

4.1 Pre-negotiation

From their respective *AOR*, the *DMs* produce individual decisions, identify potential boundary problem attributes and send the problem attributes to the *PAD* via Internet/Intranet or any other suitable networked environment. The *PAD* then sends signals to the *conflict agents* when problem attributes are received. The conflict agents are information-seeking agents as well as negotiating agents, acting on behalf of respective *DMs*. These agents are *autonomous*, *cooperative* and *mobile*. They are autonomous in that each conflict agent has knowledge about the threshold of attribute values and can initiate and perform small permissible changes at the *AOR* including the boundary regardless of the activities of the other agents. For example, if there is discrepancy in attributes a_{11}, a_{12} and a_{13} at the point where *AOR* 1, 2 and 3 intersect, three conflict agents will act on behalf of the respective *DM*s to initiate small changes when inconsistencies are minimal. Such changes aim at achieving the *DM's* goal of keeping his/her location decision intact.

The conflict agents are also cooperative as they aim at achieving a collective goal of satisficing consistency requirements at the boundary. The conflict agents are mobile so they can move from one *AOR* to another where they are required. These agents also expected to be intelligent enough to handle and schedule automated negotiation in a dynamic environment. They should have learning capabilities to learn about each *DM*'s preferences (i.e., at which times would the *DM* choose to ignore changes; what changes in the boundary decision are acceptable to the *DM*, etc.) as well as the common preferences of the *DMs* (e.g., threshold values). When automated negotiation is completed, the agents will send *A** to a *Decision Database* where the human *DM* can accept or reject the adjustments at the boundary. When the conflict is resolved at the pre-negotiation phase, there is no need to proceed to the next phase. Otherwise, when at least one *DM* rejects the changes, then a new pre-negotiation phase is initiated as long as inconsistency remains minimal. If the inconsistency is large enough to have impact on decision at the boundary and overall system, then the conflict agents will delegate the negotiation support task to the task-based agents in the next phase.

4.2 Negotiation

The task-based agents in the negotiation phase are the *Alert Manager*, *Mediator* and the *Scenario Generator*. The delegation of negotiation task is communicated to the *Mediator* through the *Alert Manager*.

The *Alert Manager* manages the alerts it receives from the conflict agents. It filters the alerts for any repetitions, assesses their urgency and schedules their delivery to the *DMs* and the *Mediator*. Inconsistency alerts will be communicated to the *DMs* via some form of user interface (e.g., visual, audio). The *Alert Manager* has capabilities to learn from past activities to further develop their skills in managing alerts.

The *Mediator* facilitates the negotiation process between the collaborating *DMs*. It captures real-time adjustments made by *DMs* and displays the adjustments via linked or networked user interface (e.g., viewer, browser, or editor). It displays information on inconsistent decision attributes, threshold violations, and overall degree of inconsistency, using visual, tabular or suitable representations. It provides virtual negotiation support by allowing the *DMs* to focus on the inconsistent attributes (*negotiation issue*s), to view changes and threshold violations (*negotiation offers*), to virtually agree on extent of adjustment and overall degree of inconsistency (*utility function*), and to come to conclusion of the second phase of negotiation process when consistency is achieved (*conflict resolution).*

When inconsistencies cannot be resolved by the above negotiation process, the *Scenario Generator* receives instructions from the *Mediator* to generate a scenario that is relevant to the current negotiation issue. One such scenario could be a change in threshold value for a particular attribute and its potential impact on overall degree of inconsistency. This scenario can be displayed via the linked viewer/editor, so that the collaborating *DMs* will become aware of the impact of changing the threshold, and can come into agreement if the impact is favourable. The *Scenario Generator* has the capability to look-ahead or perform "what-if" analysis and foresee consequences of *DMs'* actions. Scenarios can be built based on recorded actions and their results, or based on *Scenario Generator's* expert knowledge derived from learning from *DMs* domain knowledge and environmental factors influencing the decision at the boundary.

4.3 Post-Negotiation

The *Knowledge Manager* documents relevant data from the negotiation process (e.g. details of alerts, source of inconsistency, inconsistent attributes, scenarios generated, and outcome of negotiation process) and sends the record to the *Knowledge Base,* which is performing memory role. It also retrieves relevant information from the knowledge base when requested by the task-based agents. It highlights important issues arising from the recently concluded negotiation process, makes periodic review and evaluation of past negotiations, and recommends new rules or strategies for future use. Recommendations may include strategies for filtering alerts, frequency of collaboration, agreed threshold values, etc.

4.4 Tools and Methods

Because there are a number of problem attributes that influence the boundary decision, some of the agents will need tools and methods to perform their respective tasks, to work cooperatively and communicate toward achieving collective goal. In our proposed e-negotiation support model (Figure 2), we provide generic tools and methods to support task performance by the agents. These tools and methods are contained in a *Model Base* and can be accessed and reused by the agents. Most of these tools and methods will also be made available as reusable software agents. We describe some of the tools and methods that may be initially provided in the Model Base.

4.4.1 Multicriteria Methods

Each conflict agent performs multi-attribute evaluation of boundary decision. It compares multiple decision attribute values at the boundary of adjacent AOR for inconsistency. If the degree of inconsistency exceeds the threshold value, then there is conflict of decisions at the boundary. For example, the *Alert Manager* receives alerts from several conflict agents either simultaneously or at different times. To filter the alerts, the *Alert Manager* should have tools for ranking all these alerts according to some criteria such as urgency, risk, relevance and degree of inconsistency. Multicriteria ranking algorithms such as outranking relations (Roy 1990; San Pedro and Burstein 2003), utility functions (Keeney, 1992; Tewari and Maes, 2001) and different sorting algorithms will be useful methods that the *Alert Manager* can access from the Model Base. A collection of software agents, each performing a particular ranking method or sorting method, may become handy if they are stored in the Model Base, ready for action as the need arises.

When there are simultaneous initiatives for collaboration from several *DM*s, the *Mediator* can classify the requests according to decision context. For example, in weather forecasting, context can be classified as aviation, marine, thunderstorm, tropical cyclone, fire, or rainfall forecasting. Multi-criteria filtering methods (Perny 1998) or multicriteria assignment methods (Belacel 2000) can also be implemented by software agents who are programmed to perform the assignment or classification. When there are several scenarios that are related to a current inconsistency at the boundary, the *Mediator* can also access software agents from the model base to retrieve the most relevant one.

4.4.2 Resource Scheduling

Resource scheduling methods should also be accessible from the Model Base. The *Alert Manager* will need scheduling services to handle simultaneous calls for collaboration. In weather forecasting, for example, negotiation cycles need to be conducted according to the schedule of routine forecasting and warning services; or special forecast tasks such as updating or amending when the need arises.

Because of the relationships of the agents as depicted in Figure 2, resource scheduling is important to avoid conflicts of interests of agents, system breakdown, and other complexities that are inherent in networked systems. The *Mediator* can receive requests for collaboration from other conflict agents while being engaged in a negotiation process. The *Mediator* should have skills in managing simultaneous requests, and such skills may be acquired from software agents performing resource scheduling.

4.4.3 Sensitivity Analysis

The *Scenario Generator* will need to generate scenarios based on current negotiation process. The *Mediator* may present a scenario corresponding to a negotiation issue to assist the *DMs* to look-ahead and foresee the consequences of their decisions. One way to generate scenarios is through *sensitivity analysis. Sensitivity analysis* refers to analysis of impact of changes to decision outcomes resulting from individual or simultaneous changes in parameters. Small changes in attribute values or changes to threshold values, for example, may result to changes in degree of inconsistency if the decision situation at the boundary is sensitive to these changes. Different techniques for sensitivity analysis (Triantaphyllou and Sanchez, 1997) should be made available via software agents in the model base.

The *Scenario Generator* can also generate scenarios based on historical negotiation processes. A software agent performing case-based reasoning (Aamodt 1994; San Pedro and Burstein 2003) will be handy when case-based scenarios are requested by the *Mediator*. Another software agent performing data mining can also be useful when there are no similar instances of the negotiation process in the database, but where patterns or rules can be derived from the relationships of data attributes in the database (Viademonte and Burstein, 2001).

4.4.4 Metadata

Generic methods such as those described above can be accessed by agents to support task performance. Provided details of services performed by the agents can be documented and stored, we can address a knowledge management issue of identifying best practices and scientific tools and methods underlying boundary conflict resolution. We can use *metadata* as a tool for supporting communication among agents. We adopt the following definition of metadata mandated by the Australian government group for information resource description.

> *Metadata is a structured data that is used to describe resources so people searching for electronic information can find the information they are seeking more efficiently. A resource can be anything from a web page to a statue in the Parliament House. Usually resources are either informational or public services. Metadata is used succinctly to describe, manage and catalogue these resources.*

National Archives of Australia and Office for Government Online, 2000

Based on the above definition of metadata, we can identify the agents and the outcome of their services as resources. These resources can then be described, managed and catalogued. In this paper, the main purpose for proposing metadata is as a tool for supporting agent communication and for documenting agent services. Such metadata allows collection and re-use of past negotiations, or creation of negotiation scenarios to support real-time boundary conflict resolution. For example, if we use the resource description based on the Australian Government for Locator Service (AGLS) Metadata Standard, we will be identifying six mandatory elements namely: *creator, publisher, title, date, subject or function, identifier or availability* (National Archives of Australia, 2002). For the proposed e-negotiation agency, we may consider the sample resource description as in Table 1 below, describing the six mandatory elements. The AGLS was designed to be extendible so that extra elements can be added to meet specific problem domain metadata requirements.

Resource Ownership	
Creator	agentName=Mediator
Publisher	agentName=Knowledge Manager
Title	1998 Sydney to Hobart Yacht Race
Date	1998/12/26/0060
Subject	Low pressure system at Bass Strait: potential boundary conflict at Bass Strait
Coverage	(jurisdiction) Tasmanian Regional Forecasting Centre
Availability	contact=NSW RFC contact=VIC RFC contact=TAS RFC

Table 1: Sample resource description for e-negotiation support agency

In our situation, we can consider new elements to describe data relating to negotiation issues, negotiation offers and negotiation solutions to support e-negotiation process and outcome review and evaluation.

5. CONCLUSIONS

We described in this paper a multi-agent negotiation support model for boundary conflict resolution. Our initial investigation of boundary problems in marine forecasting in Australia motivated our design of the system. Marine forecasting during severe weather events would benefit from support systems that can alert forecasters of inconsistent boundary decisions which, if not detected, can lead to fatal damages or loss of lives. Our purpose for designing the e-negotiation support system is to alert the decision makers of inconsistent decisions at the boundary as well as to enhance computer-mediated and automated collaboration between forecasters to reduce inconsistencies in both the process and outcome of boundary conflict resolution. We propose a multi-agent based negotiation support system where intelligent agents perform specific tasks on behalf of human agents to support the negotiation process.

Conflict agents that are mobile, autonomous and cooperative perform automated negotiation when inconsistency at the boundary is within acceptable threshold. When inconsistency is too high to have great impact on boundary decisions and overall system, task-based agents assuming roles of alert manager, mediator, scenario generator and knowledge manager act cooperatively toward resolving conflicts at the boundary.

The intelligent agents use generic tools and methods to support task performance. Such tools and methods are contained in a model base from which agents have access. An agent performing the task of an alert manager is responsible for managing incoming alerts on inconsistency in policies from different sources. An agent performing the task of a record manager is responsible for documenting relevant details of the negotiation process whenever there is a request of collaboration from any one of the regional forecasters. Potentially, at an organisational level the *Knowledge Manager* agent can be introduced to be responsible for performing periodic reviews of the negotiation process and produces recommendations to improve future negotiation process and to reduce inconsistencies at the boundary in the future. Such review process is crucial in evaluation of the proposed negotiation support. In the BOM context, it aims at fulfilment of one of FSEP's objective of streamlining the forecast process to improve quality, quantity, timeliness, and consistency.

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