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Collaborative Air Traffic Decision Support Based on Web-based Intelligent Argumentation

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Abstract: Collaborative Decision Making (CDM) is a process of reaching consensus on a potential solution of an issue through the evaluation of the different possible alternatives. The web-based intelligent computational argumentation system allows concerned decision making agents to post their arguments on different alternatives, assign degree of strengths to their arguments and identify the most favorable alternative using our system over the internet. Agents are a group of people who participate in the argumentation process for the collaborative decision making process. Our system resolves the conflicts through intelligent argumentation and captures the rationale of the agents from their arguments. The exchange of information among the agents in the form of arguments helps them present their views and opinions and drives the group towards collective intelligence. In this article, we present an approach on how the intelligent argumentation based collaborative decision support system can facilitate the resolution of conflicts in air traffic management. It could enhance the Ground Delay Program (GDP) and help the Air Traffic Control System Command Center (ATCSCC) to take a better decision depending on the argumentation of Air Route Traffic Control Centers (ARTCC) and agents from different airlines.

Keywords: fuzzy inference engine, fuzzy association memory matrix, ATCSCC, ARTCC, ground delay program, collaborative decision support

1. Introduction

Decision making is the study of both identifying and selecting alternatives based on not only the preferences but also the priorities of agents involved in the decision making group. The process of decision making involves a close analysis of various available alternative choices. The best choice of agents would be finding the alternative with highest favorability in the group and choosing it as a final decision. Any complex engineering design issue involves scientists and design experts who make strategic decisions, resolving various issues at hand. Every issue undergoes an argumentation process in the group before a decision is taken. Thus the decision made exhibits a consensus among those agents.

A great deal of information, in the form of artifacts and arguments, is exchanged while experts work to resolve their decision making issues. Improper decisions can lead to a significant loss of capital, time, and effort. When these agents are geographically dispersed, documenting artifacts, discussions, and arguments becomes difficult. Since a large number of agents participate in the argumentation process, coordination and communication are the major challenges. An argumentation tree organizes the information so well that agents can easily understand it.

The Computer Supported Collaborative Argumentation system (CSCA) allows agents to post their arguments on different alternatives of an issue. The CSCA system allows agents to participate in the dialogue process. The computer supported argumentation systems also support collaboration work. The On-Line Intelligent Argumentation System (OLIAS) facilitates the resolution of conflicts by explicitly capturing both the rationale of the agents and the reasoning behind the arguments.

Every argument has a strength. This strength represents either the degree of support or the degree of attack to either its parent argument or an alternative directly. Each argument influences the decision alternative. The decision made by the group may not be the optimal solution but it will be the most favorable one. Collaborative Decision Making (CDM) is one of the most important aspects in any industry. In collaborative decision making, a group of people work collaboratively for the decision making process. In the argumentation based CDM process, people discuss and deliberate over the issues and solutions for developing consensus in the group. One such industry is air traffic management. Every decision in this industry is made at a high-level, strategic scenario.

The National Airspace System (NAS) in the United States is the most complex aviation system in the world. It is divided into twenty one zones known as Air Route Traffic Control Centers (ARTCC). In this application environment, the agents are geographically distributed across the country, and the decisions made are mission critical.

In this paper, we explain how the OLIAS can be used to enhance the Ground Delay Program (GDP). We demonstrate the conflict resolution problem in the GDP by presenting a developed and tested case study. This case study is hypothetical in nature.

The decision making process in a GDP involves agents, such as the air traffic control system command center, the air route traffic control center, the airlines, and other NAS users. Our OLIAS is a graphically supported CSCA system. This system allows agents

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to post their decision making issues, alternatives (positions), and arguments in an argumentation tree. Based on the dialog process carried out under various positions, the system generates the favorability factor of each position. This tool was a test bed for many other case studies involving CDM processes, such as issues related to designing a solar car, selecting a platform for the development of a mine detection tool and so forth.

In this paper we demonstrate the issue of flight slot allocation in Ground Delay Program (GDP) using OLIAS [1]. This paper is organized in the following manner. Section two presents a brief literature review on research relevant to this work. Section three discusses the OLIAS argumentation system. Section four presents the process of OLIAS, and section five provides a detailed explanation on how our argumentation system is used for the GDP in air traffic management. Section six suggests both future research work and challenges ahead followed by the conclusion of the article.

2. Related Work

This section presents the related literature work. Section 2.1 motivates the use of OLIAS for collaborative decision support in air traffic management related issues, and Section 2.2 illustrates the inability of other computer supported mass communication tools for collaborative decision support. Section 2.3 discusses the shortcomings of other existing argumentation systems, while Section 2.4 gives a very basic introduction on fuzzy logic.

2.1 Air Traffic Management

One of the primary objectives of the Federal Aviation Administration (FAA) is to both plan and apply strategic initiatives to advocate anticipated demand-capacity imbalances at airports [8]. If an imbalance is expected at an airport, traffic managers apply ground delays to flights bound for the troubled airport commensurate with the delays they would receive in an airborne queue [6]. The FAA is responsible for handling ground delay program situations. Ground delay programs typically occur due to bad weather conditions and these bad weather conditions lead to limit the number of flight operations possible. Limiting the number of flight operations leads to incurring heavy financial losses to several airlines. The current GDP plan rations the available flight operation slots at the GDP affected airport by scheduling the arrival time of the flights with some adjustments. These adjustments are made to balance the equity between airlines. Current rationing rules do not take into account the passenger flow efficiency in the rationing assignment tradeoffs [7].

Both Air Traffic Control (ATC) specialists and CDM participating airlines use the Flight Scheduled Monitor (FSM), developed by Metron Aviation Inc., to both monitor and model traffic flow management. Several scientists examined different GDP rationing rules to achieve fairness among the participating airlines. Fairness is interpreted as allocating delays equally among airlines. Several methods were used to determine how to distribute delays among airlines. The FAA command center also known as ATCSCC, other FAA facilities, and the airlines use the FSM. The FSM displays Airport Demand List (ADL) information, monitors the airport-traffic situation, and collaborates on other problems. Flight schedule monitor software both imports and displays ADL data. The ADL data enables the collaborative decision making participants to view airport demand and capacity, to list flights, to produce statistics and color-codes. The FSM displays both, a very detailed timeline display and an aggregate bar graph. A situation that could require a ground delay program is indicated when the airport capacity line on the bar graph drops below a certain threshold [8].

The current rationing rules do not consider the passenger flow efficiency in assigning slots [15]. Manley investigated the tradeoff between flight delays and passenger delays as well as airline and passenger equity in GDP slot allocation [15]. Neyshaboury et al. [16] compare and discuss the efficiency of slot allocations by the congestion pricing method and ration scheduling method. These methods are not specifically used during the GDP, but however they can be used when the demand exceeds the airport capacity. None of these developed models consider the problems associated with the airlines. Instead they pay a strict attention to both the fairness and the efficiency of the model. Airlines have a very limited opportunity to both discuss and argue with the FAA command center about the slot allocations in the present system. This is the major drawback of the existing systems.

Air traffic flow management can be improved by generating better information. This can be achieved by combining information generated by both FAA and NAS users, and distributing the same information both to FAA and NAS users [4]. The case study in this article examines how ATCSCC, ARTCC, and airlines participate in the discussion process for slot allocations using our argumentation system.

2.2 Computer Supported Collaborative Systems

Several computer supported collaborative systems are in existence today. Mass communication tools, such as emails and Weblogs, support communication among agents [12]. According to Tzagarakis et al. [20], web-based mass communication systems such as e-mail, and chat support implicit emergence in the discussion while several argumentation systems support explicit emergence. The web-based forums provide a slightly higher degree of explicit emergence than email, chat and weblogs [20].

The content and information in argumentation systems is more decentralized, while in blogs it is more central to the author. All weblogs provide email watch lists, and only some argumentation systems [10] provide email watch lists. If a post is changed, then all the agents related to that post are updated with an email about that change, this is known as an email watch list.

Email systems fail to provide a structured representation of the data to the agents. Hence, agents see a challenge in understanding the information. Also, when an agent posts an email, a group can miss an important artifact. As a result, the discussion might focus on one single point that may or may not be useful to the decision making process. Argumentation systems provide a tree structure, which is not well provided by other systems. Argumentation systems support agents in rationale capture more actively than other media, while email systems are inherently passive in rationale capture [12].

Many organizations use survey forms to determine the opinion of their employees on specific issues. A survey, however cannot allow a group of people to interact among the employees. By interacting with one another, agents gain exposure. This feature allows agents to work collectively.

Argumentation systems provide a high-level of decision making support while those mass communication tools are passive when it comes to providing decision making support [12], [20]. We can rule out the application of these mass communication systems in air traffic management related CDM issues. For further discussion please see our article [12] which presents an experiment comparing email list-serve and our argumentation system on several criteria for collaborative decision support.

2.3 Argumentation Systems

Interactions among participants are crucial for discussions, debates, and collaborative decision making. Argumentation arises among agents due to conflicting opinions. Conflicts are inevitable and cannot be avoided in discussions. Conflicting opinions lead to argumentation and debates. In a discussion process, participants manifest themselves by proper coordination and collaboration. Participants find interactions to be difficult when they are positioned throughout the world.

Scientists have addressed this challenge by developing argumentation systems over the World Wide Web. Computer-supported collaborative work allows many people to work collaboratively on computers over the web. The web allows agents to collaborate even when they are dispersed around the globe. The powerful infrastructure of the World Wide Web has motivated several researchers to work in the area of computer supported cooperative work (CSCW).

Argumentation systems either follow formal or informal argumentation models. In the literature, several systems either follow Toulmin's model of argumentation [2] or Dung's abstract model. Formal models are sound.

HERMES [11], CoPe_it! [28], and the Synergy system [29] are some of the argumentation based decision support systems. HERMES allows agents to post their issues, alternatives and arguments in an argumentation tree. This system allows agents to post scores along with their arguments. These scores are used to compute active alternatives. This system checks for inconsistencies and conflicts among the arguments. The major problem with this system is it does not perform fuzzy based argument inference. In discussions and debate, the inference of arguments is fuzzy by nature. A special variant of HERMES supports multi-criteria decision making.

CoPe_it! [28] provides multiple levels of projections in the collaboration space, which is commonly shared among agents. This system supports discussions among agents and supports decision making with the mechanism used by the HERMES system. The Synergy system [29] is a new argumentation based decision support system, where agents post their arguments with a probability score. However, this score is not used in further computations.

Several argumentation systems [25], [26], [27] have been proposed that can be used for either idea or argument mapping. These systems encourage agents to construct argument trees and participate in the argumentation process. These systems help them deliberate over the solution alternatives, however they provide a limited decision support.

The novelty of OLIAS system is providing decision support ability by computing the favorability of alternatives based on the strengths of the arguments posted under a position. Argumentation systems have been used in several areas such as law, teaching, collective discussions, and many more. The application of argumentation systems to air traffic management issues, however is new. There are several challenges in the field of argumentation systems. Klein [10] presented some of the challenges, and design issues concerned with large-scale internet enabled argumentation.

2.4 Fuzzy Logic

Fuzzy logic is a form of multi-value logic which deals with reasoning that is approximate rather than fixed values. The fuzzy logic was introduced by Lofti Zadeh. It is quite different from two-valued logic or the Boolean logic. In classical set theory, the membership of an element is either 0 or 1. In fuzzy sets, elements have a degree of membership. So, in fuzzy sets an element belongs to a set with a degree, representing its degree of membership. A membership function defines the fuzzy set. Membership functions are used to associate a degree of membership of the elements of the domain to the corresponding fuzzy set. There are several complex discrete and continuous membership functions such as triangular function, trapezoidal function and so forth [21]. Several fuzzy operators such as intersection (AND), complement (NOT) and many more are available to perform operations on fuzzy sets [22].

Though both probability and fuzzy logic deal with the problem of uncertainty, they are different. Probability theory describes the probability of an event occurring while fuzzy logic presents the degree of membership. Probability assumes independence among the events.

3. On-line Intelligent Argumentation System (OLIAS)

3.1 Background

OLIAS was developed to support collaborative decision making [1], [14]. This system is based on the Client-Server architecture. Agents can access the system using a Web browser and it is therefore accessible from anywhere in the world via the World Wide Web. This enables geographically scattered people to work collaboratively by presenting their points of view and arguments. OLIAS allows agents in the argumentation process to post their decision making issues, alternative solutions (positions) to the issue, arguments, and evidences supporting their arguments.

The server handles the access to the argumentation tree, takes care of the communication with the client, and manages the argumentation network. On the contrary, the client side has a graphical interface with an argumentation tree to display the current status of the system and a chat box to exchange information among the agents. In the argumentation network, the argument structure is organized as a weighted directed graph [1]. All of the elements in the argumentation system are presented in the form of nodes in a tree. An argument posted by an agent can be either supporting or attacking either a position or another argument.

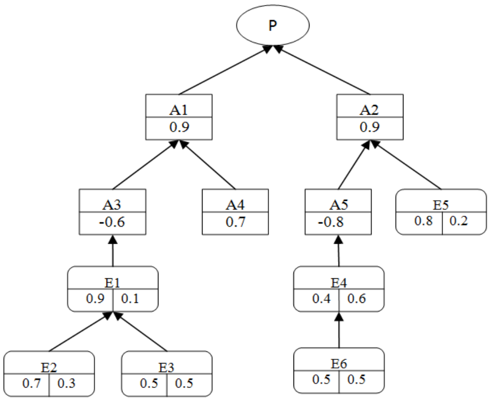

Fig. 1 Position dialog graph.

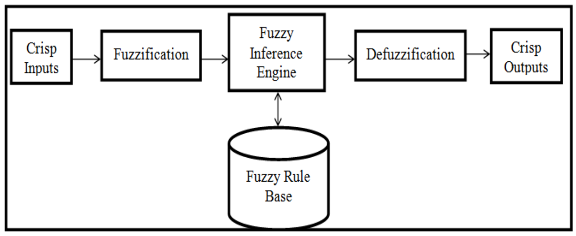

Fig. 2 Fuzzy inference system.

Figure 1 presents the position dialog graph and the root node in the graph denotes a position. The nodes denoted by rectangles are arguments, and the nodes denoted by curved rectangles represent evidences supporting those arguments. Arcs represent an association (i.e., a relationship between two nodes). The association between two nodes can be one of the following types: attack, support or indecisive. The degree of strength assigned to each argument is the strength of the argument. The strength of an argument is assigned subjectively by the agent who posted that argument. If an agent posts arguments with inflated strength it will usually result in attacking arguments from other decision agents in the group.

The strength value of an argument is a real number. This number can be between −1 and 1. A positive degree of strength denotes a support relationship. A negative degree of strength value signals an attack relationship. A zero denotes an indecisive relationship between two nodes in a tree. The labels are linguistic terms whose semantics are captured by their membership functions in our fuzzy logic based argumentation inference engine internally. The degree of strength of an argument posted by its owners will be used for fuzzy inference by the fuzzy inference engine based on fuzzy inference rules using the labels. The linguistic labels used in this system are Strong Support (SS), Medium Support (MS), Indecisive (I), Medium Attack (MA), and Strong Attack (SA).

An agent has a priority in the decision making group. This priority is assigned explicitly based on the agent's experience. Priorities can be assigned subjectively to the agents by the decision maker. Every agent is responsible for posting his/her priority while posting their arguments.

An agent is responsible to post the degree of strength of an argument and his priority score while posting his argument. The strength of an argument posted along with the argument represents its association with its parent argument. The textual description of an argument must be kept since it is used as a mechanism for justifying its strength.

The strength of the argument should be consistent with its textual content. If not, other agents will post attacking arguments. It also might be very challenging to perform inference based on the textual content, since it is difficult to understand the relationship between two arguments unless explicitly provided by the agents.

Other individuals cannot revise or assign new score to the strength already posted by others or help the agent in posting the strength. This problem has scalability issues. In the case of a huge argumentation tree with a large number of arguments, it is difficult for all the agents in the group to participate in assigning all the arguments in the tree. However, when an agent posts an argument in an argumentation tree, other agents in the decision making group can oppose or support the argument with their own arguments. Actually, untrustworthy arguments are usually attacked by other agents so that their impact on the final decision will be reduced based on our argumentation inference mechanisms. The latter argument neutralizes the strength of the former argument, if it is attacking it, and the neutralizing strength depends on the strength of the latter argument.

OLIAS is built upon the fuzzy inference system. This system takes the arguments as inputs, running them on the argumentation reduction fuzzy inference engine. The system computes the favorability factor of each position and provides collaborative decision support.

3.2 Argumentation Reduction Fuzzy Inference System

The argumentation reduction fuzzy inference system was developed to carry out the inference process in the argumentation tree. A fuzzy inference system based on fuzzy heuristic rules was developed earlier [1], [9]. The inputs to a fuzzy inference system are both the strength of an argument that must be reduced and the strength of its parent argument in the argumentation tree. The output of the fuzzy inference system is the degree of the inferred argument, which is now reduced by one level. This new degree of strength is relative to the degree of the parent argument. In this manner, the complexity of the argumentation network is reduced level-by-level using the argumentation reduction fuzzy inference system. This process is conducted to the point where every argument is directly associated with its respective position. **Figure 2** presents a block diagram of the fuzzy inference system.

The argumentation reduction fuzzy inference system is based on the following four heuristic rules. These rules are used to carry out the argumentation inference process.

Fuzzy Rule 1: If argument B supports argument A and argument A supports position P, then argument B supports position P.

Fuzzy Rule 2: If argument B attacks argument A and argument A supports position P, then argument B attacks position P.

Fuzzy Rule 3: If argument B supports argument A and argument A attacks position P, then argument B attacks position P.

Fuzzy Rule 4: If argument B attacks argument A and argument A attacks position P, then argument B supports position P.

There is another general heuristic rule involving the linguistic term indecisive. These five rules are further extended to twenty five rules based on the fuzzy linguistic variables [14]. There are five linguistic variables here strong support, medium support, indecisive, medium attack and strong attack. Twenty-five rules were developed by considering combinations of these five linguistic terms.

Twenty-five rules were thus developed and specified in the fuzzy association memory matrix according to these five fuzzy heuristic rules [1]. The OLIAS considers the priority of an agent in the argumentation computation process. The strength of an argument is reassessed based on the priority of the agent who posted the argument. After the argumentation reduction process, the system computes the favorability factor of each position by the weighted summation process. The favorability factor is computed using the degree of strengths of arguments in the reduced argumentation tree. The position with the highest favorability factor value is the most favorable position among the agents in the decision making group [1]. Each argument in the argumentation process has an effect on the favorability of a position. For more information about the fuzzy argumentation reduction process, please refer to our papers [1], [14].

4. Process of the On-line Intelligent Argumentation System

This section presents the process of the OLIAS system. First, the decision maker in the decision making group posts a decision making issue. The decision maker and other agents also post relevant positions in that argumentation tree. Both the decision maker and the agents in the decision making group participate in the argumentation process. The agents present and exchange their opinions and views in the form of arguments. They exchange their arguments over different positions in the tree. **Figure 3** presents a screenshot of our argumentation system.

The arguments in the argumentation tree undergo the inference process using the argumentation reduction fuzzy inference system. The system then computes the favorability factor for all positions posted under the decision issue. The argumentation system calculates the favorability factor of each position when the decision maker selects the decision making issue in an argumentation tree.

In the argumentation process, it is challenging to say when the argumentation will come to an end [24]. Even in real discussions and debates one would never know when the argumentation process is concluded or has come to an end. But using OLIAS, one can know the favorability factor of each alternative at any time in the decision making process.

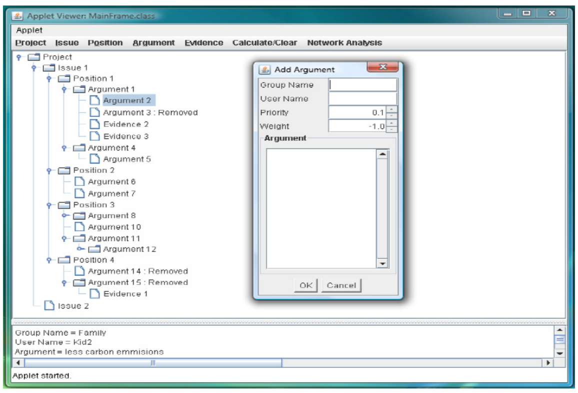

Fig. 3 A snapshot of the argumentation tree.

5. Application in Air Traffic Management

5.1 Description

The airline industry is one of the largest and growing industries. The motive behind air transportation system is to be rapid and safe transportation of both passengers and cargo and balancing the cost-effectiveness at the same time. Airline industry aids in international business investments and world trade. It is also a considerable engine of the national economy which also provides a service that cannot be achieved by other modes of transportation [3], [15]. During peak hours in the continental United States (US), approximately 5,000 flights per hour fill the sky. This number is equal to around 50,000 flights operations every day in United States. Ground Delay Program (GDP) is implemented to control air traffic volume at an airport. A GDP is executed when the traffic demand at an airport is expected to surpass the airport's acceptance rate for a long period of time. The demand surpassing the acceptance rate at an airport is a result of the acceptance rate of the airport being reduced. Weather is the most common reason for a reduction in the acceptance rate. Low ceilings, low visibility, snow, and thunderstorms are some of these. The major cause of Ground Delay Programs is weather [30], [31], [32]. Several GDP planning algorithms are developed which take weather related data as input [33]. See Tables 4 and 5 in article [30]. See Fig. 2 in article [33], a sample plot is provided for LGA airport, most of the GDPs occur during the day time. It is not necessary that a GDP occurs only during the day time, what is important here is that, the GDP occurring during day time has much more loss than the GDP occurring during night time. Since the day time operations are usually higher than the night time operations, declaring the GDP in day time has more financial and economic loss than GDP affected during night time.

In the United States, between the year 1999 and 2006, an average of 960 GDP programs per year were declared. During the first five months of 2007, more than 25 percent of domestic flights arrived more than 15 minutes late [5]. The imbalance between demand for flights and available capacity is estimated to cost passengers between $3 billion and $5 billion a year in trip delays [7]. During the Ground Delay Program, the number of flights that should be operated must be reduced to a given level. So the Air Traffic Control System Command center (ATCSCC) downsizes the number of flight operations for each airline in order to achieve a balance between the demand and the acceptance rate of the flights at the airport. Thus, the ATCSCC must make a reasonable solution to reduce the flight operations in each airline while maintaining fairness among all airlines. The ATCSCC needs to ration the flights among all airlines. Sometimes the airlines may not be happy with the number of flight operations allocated to them.

OLIAS allows the airlines to argue the issues for which they are unsatisfied. The following section focuses on a case study, developed and tested on our argumentation system. Our system introduces argumentation among the ATCSCC, the ARTCC, air-

Table 1 Flight operations of airlines.

Airlines	Flight operations / hour
Airline 1	40 operations / hour
Airline 2	24 operations / hour
Airline 3	36 operations / hour

lines and other National Air Space users. There will be an improvement in the quality of information exchanged and it could possibly enhance the GDP planning process. Ultimately, our system can improve collaborative decision making among agents.

Our intelligent argumentation technique is for collaborative decision support. It is not applicable in the cases where decisions must be made without any discussions, and the Ground delay program (GDP) design and planning is performed before the situation arises.

5.2 Case Study

Now we present a hypothetical application case study of argumentation based decision support in air traffic management. Let us suppose that, due to incremental weather conditions, a large-hub airport, such as Chicago ORD, decides to reduce its operational capacity. This reduction will initiate the GDP program. Reducing the flight operations will need to be discussed via a conference-call among agents at the ATCSCC. In our case study, the ATCSCC will post both the issue and its possible positions in the OLIAS. Other agents can also post their positions if they believe the positions meet the criteria set by the ATCSCC.

5.2.1 The Issue

Let us assume that the Chicago ORD airport has 100 flight operations per hour. Due to the GDP, these flight operations must be reduced to 45–60 operations per hour. The length of the GDP affected period is assumed to be one hour. The GDP is also assumed to occur during the day, since in general GDP occurs more often during day time. Airline 1 has its hub in the Chicago ORD airport. Airline 3 operates more international flights than domestic flights during the GDP affected hour. **Table 1** illustrates all of the airlines involved in this case study.

Table 1 illustrates that Airline 1 is operating forty flights per hour. Airline 2 operates twenty four flights per hour, and Airline 3 has thirty six flight operations per hour. Airline 3 operates with more passengers than the other two airlines. It also has more international than domestic flights during that GDP affected hour.

5.2.2 The Decision Agents

Agents are individuals who either can affect or are affected by the achievement of an objective in a project. Hanowsky and Sussman [17] discussed the importance of a stakeholder's perspective in designing of ground delay programs. They generalized stakeholders in GDP based on Mitchell's theory [18]. According to Hanowsky et al. [17], power, legitimacy and urgency are three different criteria on which stakeholders are selected to be part of the decision making group for a GDP [17].

- Power: the ability to affect the design or outcome of a GDP,
- Legitimacy: the degree to which GDPs affect a group, and
- Urgency: the need perceived by a group to change a GDP.

We had five agents involved in our decision making process. ATCSCC was utilized as the command center. Their role was to manage the flow of air traffic within the continental United States. ARTCC was responsible for controlling the instrument flight rules for aircraft enroute, in a particular volume of airspace, at high altitudes. We used three airlines: Airline 1, Airline 2, and Airline 3. We demonstrated the case study with only three airlines, to keep the case study simple and explain the process clearly and in detail. This experiment, however, can be further scaled to more agents and more complicated air traffic management issues can be illustrated.

Table 2 Priorities of the decision agents in the decision making group.

Agent	Priority
ATCSCC	0.9
ARTCC	0.6
Airline 1	0.3
Airline 2	0.3
Airline 3	0.3

In our case study, we only considered one ARTCC representative as a decision agent. Since, only Chicago ORD international airport is affected by inclined weather conditions, and the airport is in one zone (ARTCC), we considered one ARTCC as an agent. We could however, include several other ARTCC representatives as decision agents in the argumentation process. OLIAS is scalable and can support more number of agents [12].

Each agent was given a priority in the system. The priority of an agent in a group was assigned by the group subjectively. Priority value ranges between 0.1 and 1. A higher value of priority implied a higher influence in the decision making scenario. A lower value of priority implied a lower influence. This priority was used to assess the strength of an argument [9]. This influences the favorability factor of an alternative.

All three airlines in the case study were provided the same priority to demonstrate fairness among them in the collaborative argumentation process. The decision maker can however assign different priorities to agents based on their profile [9]. Traffic flow managers and business managers from each airline can represent their organization to participate in the discussion process. **Table 2** presents the priority of each agent in this case study.

5.2.3 The Positions

An alternative, or a position, is a candidate solution for the given decision problem. ATCSCC posts the decision issues along with the positions. The following hierarchy (**Fig. 4**) illustrates all of the positions for the given issue.

Five alternatives (positions) were posted for the given decision making issue. The first two positions are provided by the ATCSCC, and the remaining three positions are provided by the airlines. Each position was a plan. Each position actually tells how the flight operations slots have to be assigned to each airline. The first two positions followed the equity, and all of the airlines were given an equal number of operational slots. Fairness existed among the airlines in the first two positions. The third position was posted by airline 1, the fourth by airline 2, and the fifth by airline 3. All of the three positions posted by the airliners were in their own favor. Each position obeyed the criteria set by the ATCSCC for a position. The total number of flight operations had to be between forty five and sixty. The following description

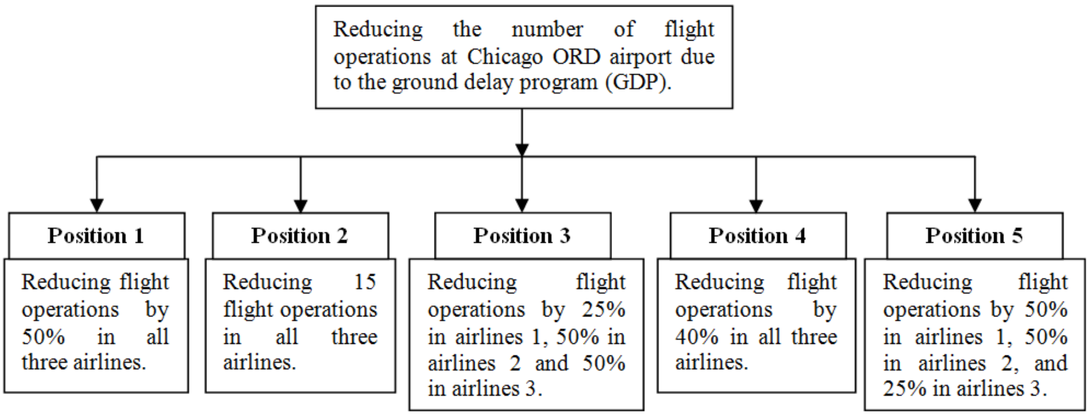

Fig. 4 Five positions for the given decision making issue.

Table 3 Five positions for the issue and their flight slot allocation.

	Reducing flight operations by 50% in all airlines.	Reducing 15 flight operations in each airline.	Reducing 25% in Airline 1, 50% in Airline 2, 50% in Airline 3.	Reducing flight operations by 40% in all airlines.	Reducing 50% in Airline 1, 50% in Airline 2, 25% in Airline 3.
Airline 1	20	25	30	24	20
Airline 2	12	9	12	14	12
Airline 3	18	21	18	21	27
Total flight operations	50	55	60	59	59

provides a detailed discussion about the five positions.

Position 1 – Reducing flight operations by 50% in all three airlines. This reduction indicates that airlines 1, 2, and 3 had to reduce their flight operations by 50% during that GDP affected hour.

Position 2 – Reducing fifteen flight operations in all three airlines. This reduction indicates that airlines 1, 2, and 3 had to reduce fifteen flight operations from each of their schedules.

Position 3 – Reducing flight operations by 25% in Airline 1, 50% in Airline 2, and 50% in Airline 3. This reduction indicates that Airline 1 could operate only 75% of their scheduled flights. Airline 2 can operate only 50% and Airline 3 can operate only 50% of their scheduled flights. This position was originally posted by airline 1. This position was intuitively favorable to airline 1.

Position 4 – Reducing flight operations by 40% in all three airlines. This position indicates that all three airlines can only operate 60% of their total scheduled flights. This position was posted by airline 2 in their own favor.

Position 5 – Reducing flight operations by 50% in Airline 1, 50% in Airline 2, and 25% in Airline 3. This position was posted by airline 3 in their own favor. This position allowed airline 3 to operate 75% of their scheduled flights by cutting down only 25% of their flight operations, while Airline 1 and Airline 2 can only operate 50% of their scheduled flight operations.

5.2.4 The Argumentation Framework

This section explains how the OLIAS is used in air traffic management. Initially, the ATCSCC center identifies both the issues and its possible positions. The agents then participate in the argumentation process by posting arguments on the positions listed by ATCSCC. They can post their arguments either against an alternative or in support of it. They can also post supporting evidences. Additionally, an argument can either support or attack another argument. Once the argumentation process is complete, the system computes the favorable position. The output of the system is the favorability value of all five positions posted in the tree. **Figure 5** illustrates the argumentation framework of the application of air traffic management in our argumentation system.

5.2.5 The Argumentation Tree

Figure 6 presents a snapshot of the argumentation tree of the flight slots allocation decision issue in the air traffic management. The argumentation tree is developed by the agents. It evolves as the agents post their arguments under the positions in the tree. We present five different figures (**Figs. 7**, **8**, **9**, **10** and **11**). Each figure represents the argumentation tree of a position. The ovals at the top of the figure are the positions. The remaining boxes are the arguments in the tree. These arguments are specified by the labels A, B, C, D, and E for positions 1, 2, 3, 4, and 5 respectively.

These arguments also have indexes associated with them. Beneath the label are two boxes. The box on the left indicates the degree of strength of the argument. The box on the right indicates the priority of the agent who posted the argument. The degree of strength is between −1 and +1. The priority of the agent is between 0.1 and 1. When an argument is posted, the agent should indicate his/her name, the strength of the argument and the pri-

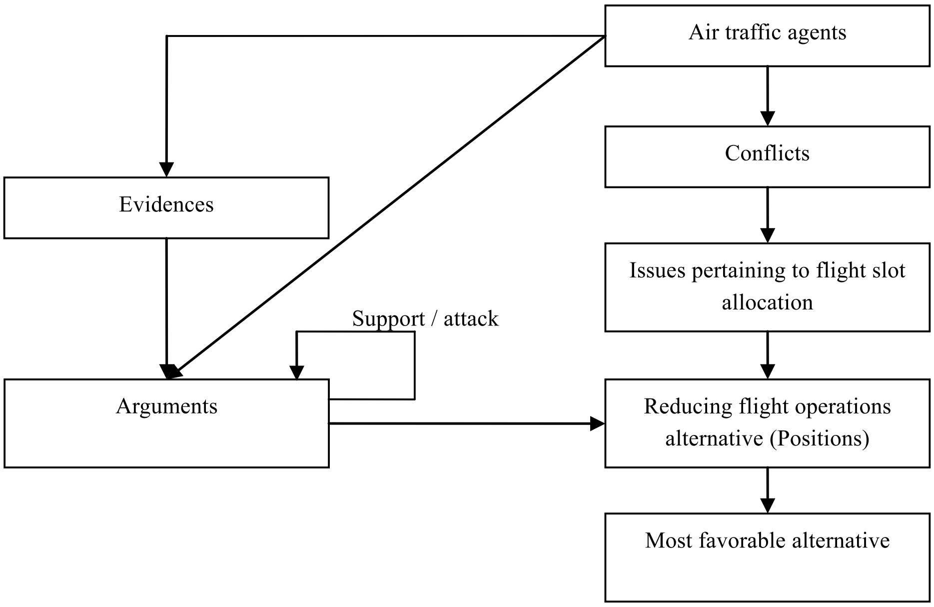

Fig. 5 Argumentation framework for reducing flight operations issue in air traffic management.

Fig. 6 Argumentation tree of flight slot allocation issue in air traffic management.

ority. Using the mechanism [1] specified in Section 3.2 in this article, the arguments undergo the inference process. Finally, the weighted summation technique is used to compute the favorability factor of a position.

The arguments presented in Figs. 7, 8, 9, 10 and 11 are as follows:

A1-This position has the minimum number of flight operations among all the positions.

A1.1-It satisfies the range of 45-60 flight operations per hour as suggested.

A2-There is no equity problem in this alternative. Fairness is maintained among the airlines.

A3-This position operates 50 flight operations per hour. It is the best one among all the positions.

A4-It is difficult to cut down 50% of flights. It would be better if 40% is cut down, still the equity is maintained.

A4.1-This idea would be really great, I can reduce my financial loss to a great extent.

A4.2-Passenger delay could be reduced.

A4.3-The sector workload will be relatively more.

A5-Workload in sectors is relatively better with this position.

A6-I have my hub in this airport, I need less cut down of my flights. 50% really affects my economy.

A6.1-Customer satisfaction and reputation of the airlines goes down with this alternative.

A6.2-I do not have any flight operation slots to exchange with you.

A6.2.1-I am running short of flight operation slots. I am not in a position to exchange slots.

B1-This position is better than position 1. It has more number of flight operations.

B2-This position has 55 flight operations per hour. It is a good position.

B3-I have many international flights during this time. This position doesn't work with me.

B3.1-We can exchange a flight operation slot.

B4-This position has more sector work load relatively.

B5-I have my hub in this airport, so I expect more flight operation slots for me.

C1-Equity among the airlines is not maintained.

C1.1-It is same as position 1 in terms of airline 2. You get the same number of flight operation slots.

C1.2-Airline 1 is given more priority over airline 2 and airline 3.

C2-This alternative drives me to less financial loss relatively.

C3-This position operates 60 flights, highest possible value in the given range which is not that good in terms of safety.

C3.1-Fewer number of flight cancellations relatively.

C3.1.1-Workload is highest in this alternative.

C3.1.2-Customer satisfaction will be better.

C3.2-Overall passenger delay can be reduced.

D1-Equity among the airlines is maintained.

D1.1-Less number of flight cancellations are performed relatively.

D2-This position has 59 flight operations per hour. It satisfies the condition given by the ATCSCC.

D3-This position is really great, I can reduce my financial loss to a great extent.

D3.1-Passengers delay could be reduced to a great extent.

D4-This position has high workload in the sector.

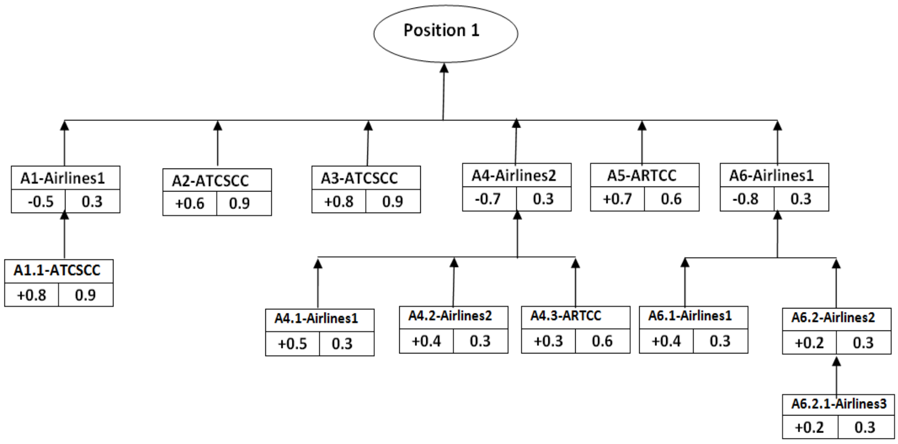

Fig. 7 Argumentation tree constructed by the agents under position 1.

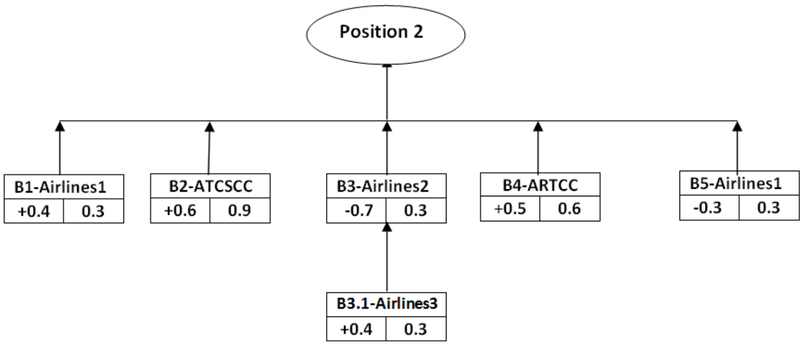

Fig. 8 Argumentation tree constructed by the agents under position 2.

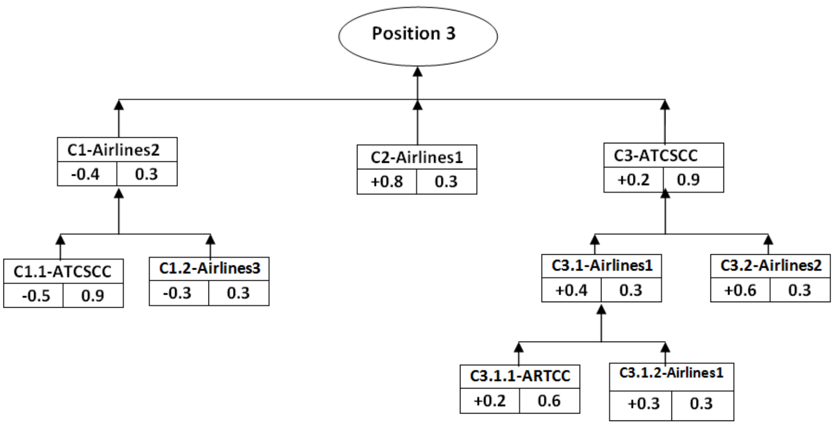

Fig. 9 Argumentation tree constructed by the agents under position 3.

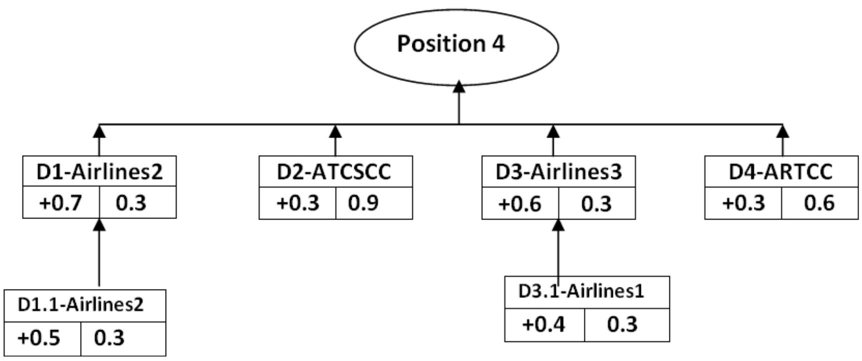

Fig. 10 Argumentation tree constructed by the agents under position 4.

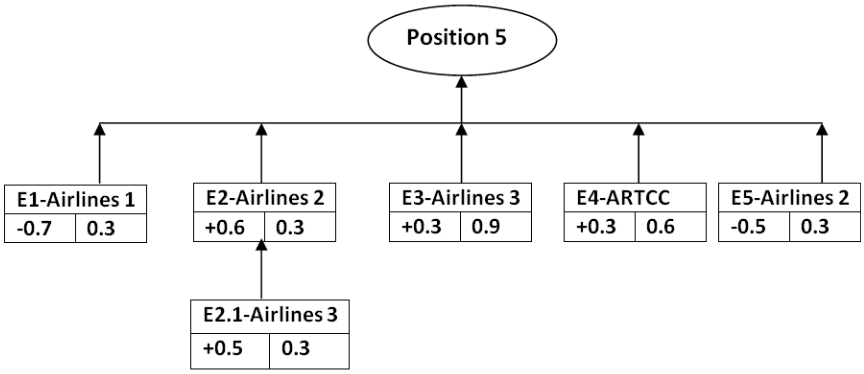

Fig. 11 Argumentation tree constructed by the agents under position 5.

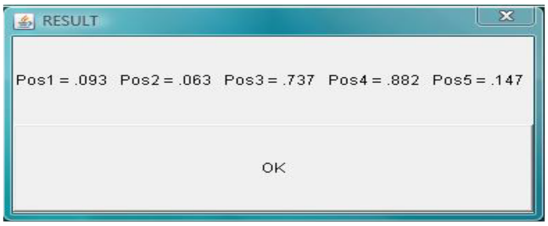

Fig. 12 Favorability factor of positions produced by the OLIAS.

E1-Equity among airlines is not maintained. This position is more favorable to airline 3.
E2-Passengers delay could be reduced to a great extent.
E2.1-This position would be really great, I can reduce my financial loss to a great extent.
E3-This position has 59 flight operations per hour. It satisfies the condition given by the ATCSCC.
E4-This position has high sector workload.
E5-I have many international flights during this time. This position does not work for me.

The agents in this case study exchanged only thirty nine arguments in the dialog process altogether under five different positions. More arguments could be exchanged among the agents however it totally depends on the decision making agents. Earlier in one of our experiments twenty four agents exchanged 695 arguments altogether on three different decision making issues [19].

5.2.6 The Favorability Factor

After the argumentation process, the decision maker selects an issue from the argumentation tree to compute the favorability factor of all positions. **Figure 12** illustrates the favorability factor of all five positions. Position 4 had the highest favorability factor, indicating position 4 is the most favorable position among the agents. Therefore, position 4 is the winning alternative. Position 2 is the least favorable one among all five positions posted. Reducing flight operations by 40% in all airlines is the most favorable alternative. The position with highest favorability factor follows the constraints provided by the air traffic control system command center (ATCSCC).

As the dialog process unfolds people get to know the priorities and opinions of others in the decision making group and it helps them capture the rationale through the arguments. The favorability factor presents the decision making group's favorability towards an alternative. The best decision is selected here in the GDP problem, the most financial impact on airlines is reduced and passengers could save their time. A strategic decision in air traffic management impacts several airlines, passengers and employees. These types of decisions are closely related to the financial and economic issues.

Our approach to argumentation based collaborative decision support is to allow agents to express their intentions and conduct negotiations by explicitly presenting their arguments and evidences. Every argument posted by an agent in an argumentation tree influences the final outcome produced by the OLIAS. The degree of strength of an argument posted along with the argument by an agent supporting or attacking an alternative affects the favorability factor of that position. An agent might post any number of arguments and influence the final outcome, but those arguments should not be redundant. An argument posted should be based on a reason. One could also post evidences supporting their arguments. If an argument posted by an agent is not reasonable from another individual's point of view, then the other individual can oppose with his own arguments.

6. Future Work

We are developing some argumentation metrics that provide decision support to agents and encourage them to participate in the argumentation process. Decision agents in the argumentation process based on the similarity of their opinions polarize and form groups, called polarization groups. Agents in these groups support among themselves. We are developing methods to identify these polarization groups, and also to assess an agent's degree of membership in multiple polarization groups, since these groups overlap [23]. Currently, we are conducting experiments to identify decision agents with outlier opinions in the argumentation process.

7. Concluding Remarks

This paper discusses how to use the online intelligent argumentation system to facilitate the resolution of conflicts in air traffic management. Intelligent computational argumentation-based conflict resolution improves the exchange of information and opinions among the agents who are in geographically distributed locations. When applied to air traffic management, ATCSCC can better understand both the viewpoints and preferences of airlines. This system, when used in air traffic management for resolving conflicts, benefits the concerned agents by bringing in transparency in the decision process. The airlines and passengers can benefit when more informed decisions are taken by the GDP decision maker. The results demonstrate the feasibility of collaborative decision support through intelligent argumentation among decision making agents.

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