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Semantic Enhanced Argumentation Based Group Decision Making for Complex Problems

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Chapter 2 Literature Review

Abstract: In this chapter, a critical review on the theory and practice of decision making and argumentation is given. Firstly, the decision theory and argumentation theory are discussed; secondly the existing practice of decision support and argumentation support are reviewed; thirdly theoretical frameworks of argumentation based decision making are presented and discussed, particularly a considerable number of argumentation based group decision making system are reviewed and analysed, the issues and gaps in those research are identified; finally based on the review some requirements and recommendations for the conceptual framework of semantic enhanced group argumentation based decision making are proposed.

Keywords: critical review, decision theory, argumentation theory, argumentation based group decision support system.

2.1 Decision Making

2.1.1 Decision Making Theory

Decisions are not just an “act of choice”; they are the result of a “decision process”, a set of cognitive activities enabling to go from a “problem” to its “solution”. The decision process is not a process only about solving a problem, but also implies understanding and shaping a decision problem. (Ouerdane et al, 2009)

In classical decision theory, the decision problems are assumed to be well defined, and the actions and outcomes are assumed to be fixed to start with. The decision making is concerned with identifying the best decision to take, assuming an ideal decision maker who is fully informed, able to compute with perfect accuracy, and fully rational. So decision making can be viewed as the solution of an elegant mathematical problem. The most systematic and comprehensive software tools developed in this way are called decision support systems (DSS).

However, researchers in “problem structure methodologies” argue that decision making is not just to offer a solution to a well established mathematically formulated problem, but to be able to support the whole decision process, including representing the problem, formulating a problem and possibly proposing a reasonable recommendation (Rittel et al,1973; Franco et al,2006). In AI research, the decision making is usually based on the representation of the agent’s preference and its knowledge or cognitive attitudes, like the agents’ belief, desire and intention to take actions (called BDI architecture, Bratman, 1987), which are expressive and intelligible to the human user and allow the decision maker to represent and reason about the underlying reasons motivating the particular decision. This kind of reasoning is based on the rationale of decision. Due to the dynamic of agents’ preference and limitations of agents’ knowledge, the decision process encompasses basic analytical elements which should be able to

- capture the feedback loops present in the decision process;
- account for the inconsistencies which may appear during the decision process;
- account for irreducible uncertainties;

- consider revisions and updates in the course of the decision process

2.1.2 Generic Process and New Paradigm of Decision Support System

Courtney (2001) summarises a more commonly used model of the decision-making process in a DSS environment as Figure 2.1. In fact, this model can clearly divide the decision process into steps as recognizing and analysing problem, proposing alternatives and designing the evaluation model and evaluating alternatives to get optimization.

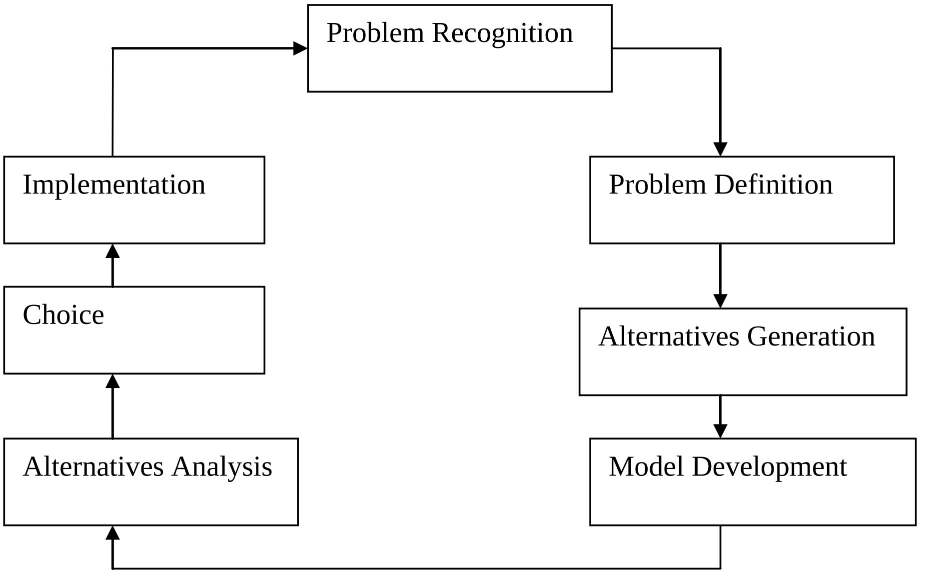

Figure 2.1 The Conventional Decision-making process model

Courtney argues that in an ill-structured situation of complex problems, no decision process is clear-cut like this. Typically, the various phases overlap and blend together. So the artificial division of knowledge into disciplines and the reduction of complex problems into simple components inhibit the solution to social and management problems. Solving complex problems may require knowledge from any source and those knowledgeable in any discipline or profession. As illustrated in Fig1.1 in Chapter 1, Courtney proposes a new DSS paradigm in which the mental model is at the heart of this process. It either personally or collectively determines what data and what perspectives are examined in the redundant data source of the problem domain.

These mental models are also constantly updated along with the whole process. As perspectives are developed, insight is gained and the mental models are updated. So a learning process takes place. Comparing with these two paradigms, the conventional DSS paradigm would concentrate on the engineering aspects of the decision making process, however the new DSS paradigm would more concern the mental model update and various perspectives synthesis. In the latter case, apart from typical DSS approaches (intelligence, design, and choice) learning, communication and consensus development tools are highly required.

2.2 Argumentation

Argumentation is defined as the study of different aspects of human interactions, whose objective is to reach a conclusion about the truth of a proposition or the adoption of a course of action (Reed et al, 2004). The aspects of argumentation study include the argumentation interaction, typically referring to communication dialogue; the interpretation of arguments, the knowledge representation for building and interpreting arguments; and applications such as agent negotiation, legal argument, and decision making support.

2.2.1 Argumentation Theory

Argumentation refers to a process of reasoning, but it has also been used to denote the manifestations of reasoning process (e.g. minutes of meeting, letters, telephone and other conversations) (Tweed et al, 1998).

The theory of argumentation is descriptive of how people argue. The theory has roots in logic. In the standard classical logics (propositional, predicate), if a conclusion is logically implied by a set of propositions, it will always remain true. No additional information can cause the conclusion to be modified. Apparently classical reasoning, as a kind of monotonic reasoning, cannot deal with much of our everyday reasoning such as commonsense reasoning, practical reasoning etc. in which the circumstance of incomplete and inconsistent information often occurs. Contrasted with standard classical logics, in argumentation, the conclusions are frequently made on the basis of new information. And these conclusions are only provisional and may be retracted if a new opposite case occurs. This kind of reasoning is called as Defeasible Reasoning and was introduced to the AI field by the philosopher John Pollock (Pollock, 1987) in the mid 80's. The argumentation formalisms are Defeasible Reasoning systems which work by considering the reasons that lead to a given conclusion (or claim) through a piece of reasoning (supporting arguments) and the potential challenges (counter-arguments) for rejecting that conclusion. This mechanism proposed a dialectical process, during which the exchange of arguments and counter-arguments respectively promote and challenge the claim of the initial argument.

Toulmin developed his theory in order to explain and analyse everyday argumentation (Toulmin, 1958). The six main components in a completed argumentation diagram include data, warrant, claim, backing, rebuttal, and qualifier. Data refers to the facts or belief, Claim refers to the conclusion and warrant is the "leap" from data to a claim, Backing refers to the credential designed to certify the statement expressed in the warrant, Rebuttal refers to the statements recognizing the restrictions which may be applied to the claim, Qualifier refers to the degree of force or certainty concerning the claim. Specifically the task of the warrant is to register explicitly the legitimacy of the step involved and to refer it back to the larger class of steps whose legitimacy is being proposed. Referring to Toulmin's work, Brockriede et al (1960) describe an argument as "movement from accepted data, through a warrant, to a claim." The rebuttal component gives the speaker a chance to expose the restriction of the claim, which could lead to retraction of the original claim.

Argument schemes are the general form of argument, whereby given a set of premises a conclusion can be drawn. However, due to the defeasible nature of argument the schemes allow for arguments to be presented within a particular context and be altered in the light of new evidence or exception to rules. Walton (Walton et al, 1996) describes two argument devices – schemes and critical question. The first is used to identify the premises and conclusion; and the second one is for evaluating the argument by raising a critical question toward its potential weaknesses. These argument devices are widely adopted in the development of an argumentation support system to facilitate the user to make high quality argumentation and provide formal guidance for argumentation analysis and evaluation.

In most AI oriented approaches, argumentation often takes place against the background of an inconsistent knowledge base. In this context, argumentation is a method for deducing a justified conclusion depending on attack and defeat relations among the arguments which can be constructed from the knowledge base. Dung's abstract argumentation framework (Dung, 1995) is most widely adopted in this kind of research, where the main concern is to find the set of arguments which are considered as acceptable argument, and to find sets of arguments which represent coherent points of view. The abstract argumentation framework is represented as a pair like (Arg, att), where Arg is a set of arguments and att $\subseteq$ Arg $\times$ Arg is a binary relation representing attacks between arguments. The acceptability of the argumentation can be dialectically measured in a qualitative way by different extensions based semantics such as admissible extension, preferred extension and stable extension etc. Although each argumentation semantic extension represents a different pattern of inference, all of them have in common that each is an admissible set which represent a coherent point of view in a conflict of arguments. Based on Dung's abstract argumentation framework, many extensions have been proposed such as value-based argumentation framework (Bench-Capon, 2003), preference-based argumentation framework (Amgoud et al, 2002) etc. in which the value the argument can promote or the preference the argument is related with can be used to evaluate the acceptability of the argument based on the attack relation between arguments. From the acceptable argument sets, the justified conclusion can be deduced without any inconsistency. Dung's abstract argumentation framework and its extensions are often used in agent based automatic decision making, in which argument is represented as symbolic logic in the knowledge base.

Apart from logic and dialectic, communication or interaction is another very important aspect of argumentation. Concepts and standards of communication and interaction regulate how an actual dispute can be conducted, which includes how agents can introduce or challenge new information, how agents state the argument, what type of utterance is essential for argument, and what types of relationship between different utterances are required. In other words, the possible speech acts and discourse rules to manipulate them have to be defined. In fact, the information provided by those interactions in the argumentation for constructing and evaluating argument is not only constrained to the attacking or supporting argument, but also it can question or concede a statement or whether a decision has been taken accepting or rejecting a claim. Walton et al (1995) define a classification of dialogue types used in human communication: Persuasion, Negotiation, Inquiry, Information-Seeking, and Deliberation. Modelling and formalizing different types of dialogue are often adopted in the development of collaborative argumentation systems and also used to capture the process of deliberation of problem solving in some highly intelligent personal or group activity such as product design, or scientific discourse. (Conklin et al, 1987; Shum et al, 2003)

In other research, some studies focus on the construction and the identification of argument schemes in the context of decision making. Those researches aim to represent the process of the reasoning from decision makers by constructing arguments in favour of and against decision and draw a conclusion by comparing these arguments. In the following sections, some of these approaches will be discussed.

2.2.2 Argumentation in Practice

The above introduced argumentation theory describes 3 layers in the argumentation processes, which respectively are logic, dialectic and interaction. In recent decades, there are many practical developments in a range of areas based on argumentation theory such as multi-agent, collaborative work, semantic web, decision making. This section presents some brief reviews regarding major argumentation based application areas, which will help to distinguish the area of our research in the argumentation domains.

2.2.2.1 Argumentation in Multi-Agent System

In the Multi-Agent System (MAS) area, there is wide range of problems which can be considered from the argumentation perspective. First of all, in the multi-agent community, agents communicate with others having intention to negotiate, persuade, dispute or collaborate etc. Argumentation as the interaction of different arguments for and against conclusions can act as an engine involved with the giving and receiving of reasons. It has made solid contributions to Multi-Agent dialogues. As concepts of the argumentation theory, argumentation schemes (Walton, 1996) and dialogue games (Hamblin, 1970) have also been employed to structure the dialogue between agents according to predefined interaction rules. The protocol about specific types of dialogues include inquiry (Hulstijn, 2000), persuasion (Atkinson, 2005), negotiation (Jin et al, 2004) and deliberation (McBurney et al, 2007). Furthermore, some researchers have more concern about automatically generating argumentation, and argumentation strategy based on different notions of position (agent's own knowledge, opponent's model, possible moves etc.) during agents' interaction. (Rovatsos et al, 2005; Rahwan et al, 2008; Neves et al, 2006)

Secondly openness and dynamicity are the main characteristics in MAS. The modification of environment or introduction of new information may give rise to new arguments that reinforce or weaken certain beliefs. So the argumentation techniques can be applied to revise the agents' belief in the condition of incomplete or uncertain information. Capobianco et al (2005) apply argumentation to maintain the consistency of the agent's mental state in changing environments by well representing the environment and integrating the new information in the belief update process. Argumentation is also applied in MAS as a selection approach between conflicting desires (Amgoud, 2003) and objectives (Amgoud et al, 2004b). In addition, the expected value of the realization of certain actions can be reasoned by the argumentation (Fox et al, 1998)

Thirdly in MAS the theoretical reasoning about the state of the world and the effects of the potential action to perform is not adequate for deciding which action should be taken in a particular situation. The argumentation theory has been studied in MAS to manage the agent's practical reasoning which can decide how the agent acts in the particular situation. Each agent has its own point of view and its particular objectives and preference. Practical reasoning can be understood by agents as determining a plan of action. Atkinson (2005) develops a model of argumentation processes by which the agent can reason about what is the best action to perform. And Rahwan et al (2006) propose an argumentation based approach for practical reasoning, which can be used by an agent to generate consistent desires and plans to achieve them.

2.2.2.2 Argumentation in Semantic Web

Openness, incompleteness and coexistence of contradictory information are fundamental traits of the Web. The popularity of web development indicates these traits are not limitations but rather an asset of the web. The semantic web adds a semantic layer with formalized ontology, rules and standards on top of the traditional web for better integrating and consuming distributed information, but all of them are still consistent with the open nature of the traditional web. Argumentation theory enabling reasoning and explanation under incomplete and uncertain information has been claimed to have good potential to use in different aspects of the semantic web. (Torroni et al, 2009)

Some initial efforts have been made to create tools to facilitate structured web discussion such as TruthMapping[1] and Discourse DB[2]. Those web based tools provide an intuitive interface to better enable the users to engage in structured argumentation dialogues and organise them in a simplified structure and also export the content in RDF format for intelligent usage. Following this direction, Rahwan et al. (2007) extend the recently proposed Argument Interchange Format (AIF) (Chesnevar et al., 2007) and adopt Walton's general argumentation scheme to develop an ontology of the arguments using the RDF Schema Ontology language. The authors also present a semantic web based prototype system, ArgDF, for authoring, navigating, querying and reusing arguments. The aim of this research is to lay theoretical and software foundations for a World Wide Argument Web and attempt a standard ontology of the argumentation.

In recent years, researchers have paid more attention to domain related argumentation (Shum et al, 2003; Passant et al, 2009). Contrasted with general argumentation structure, the domain specific argumentation model has more enriched semantic classification of the arguments and relation between them. In (Shum et al, 2003), a scholarly argumentation ontology is developed in which the argument relation is not only constrained to attack/support but also extend to more domain particular terminology such as "is consistent with" "is inconsistent with" "shares issue with" "is analogous to" "causes" and so on. The scholar discourse can be represented by the scholarly claims and linkages between them. The enriched argumentation relations allow the intelligent agent to interpret structured scholarly argumentation in a meaningful way and answer the users' semantic query based on the argumentation asset. For example, the system can answer questions like "what experiments support

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[1] http://www.truthmapping.com.

[2] http://discoursedb.org/wiki/Talk:DiscourseDB:About

this conclusion?" or "what other approaches share an issue with this one?". In (Teufel, 1999), different from Shum's approach, based on argumentation moves in scholarly papers, Teufel classifies different roles for chunks of text in the research paper such as background, aims, own, contrast etc. An approach for automatically assigning argumentation roles to the sentences is proposed. Argumentation zone based annotation has been applied to support semantic information retrieval by query expansion based on argumentative criteria (Ruch et al, 2006). For example, the user can search for "which research papers aim to resolve this research problem?".

In current social network systems, a large amount of conversation in 'web 2.0' media such as blog, wiki, forum etc. often links the online community together. Some preliminary studies have been conducted to combine the argumentation model with the social semantic model in order to semantically integrate the large scale information from all aspects. In (Benn et al, 2005), an ontology-based approach is reported to model the argumentative discourse, texts and community in academic domain in order to support semantic browsing, searching and domain visualising. In (Passant et al, 2009), authors align scientific discourse ontology and online communities ontology together to make the discourse structure and community relationships more accessible to computation so that the argumentative information can be better navigated, compared and understood cross or within domain.

In the context of semantic web, argumentation not only can support to handle the issues about content integration, information acquisition which have been mention above; but also an argumentation approach has been reported to support machine-human dialogues, machine-machine dialogues or human-human dialogues for ontology creation (Tempich et al, 2007) and ontology mapping and alignment (Laera1 et al, 2006). Engineering a shared ontology, as a crucial factor for the success of the semantic web, is a social, evolving process which involves a geographically dispersed community and expertise. An argumentation based approach can foster consensus building and the creation of a truly shared ontology.

2.2.2.3 Argumentation in Computer Supported Collaborative Work

Computer Supported Collaborative work addresses the issue of how collaborative activities and their coordination can be supported by means of computer systems (Carstensen et al, 1999). In human collaborative work, argumentation is the common way to exchange information by presenting or linking different ideas. Furthermore computer supported deliberative argumentation can explicitly capture and structure the individual rationale of solving problem which can be easily understood and argued by other group members. In (Arai et al, 2010), a meeting assistant system is developed which structurally records the utterances to produce meeting minutes from the output of a meeting by collaborative editing and visualization of the argument structure. In many collaborative design systems, argumentation models are used to provide a means to record and communicate the individual deliberation and reasoning behind the design process. The prominent argumentation models for formally capturing the design rationale include Toulmin model (Toulmin, 1958), IBIS (Issue-Based Information System) model (Conklin et al, 1988), QOC (Questions, Options, and Criteria) model (Maclean et al, 1991) and WinWin model (Bose, 1995). In some collaborative authoring systems (Li et al, 2002; Uren et al 2006), the argumentation approaches are used to link different ideas or information using argumentative terms. Comparing with the traditional hyperlink system, linking information by semantic enriched argumentative term can better index, query, visualize and manipulate the published information.

2.3 Decision Support System (DSS)

2.3.1 Classification of DSS

The term "decision support systems" first appeared in (Gorry et al, 1971), in which a DSS is defined as a computer system that deals with a problem at least some stage of which was semi-structured or unstructured. A computer system could be developed to deal with the structured portion of a DSS problem, but the judgment of the decision maker was brought to bear on the unstructured part, hence, constituting a human-machine system. The aim of early stage DSS development was to create an environment in which the human decision maker and the IT-based system worked together in an interactive fashion to solve problems; the human dealing with the complex unstructured parts of the problem, the information system providing assistance by automating the structured elements of the decision situation (Arnott et al, 2005). Now it has been evolved to include personal decision support systems (PDSS), group decision support systems (GSS), negotiation support system (NSS), intelligent decision support systems (IDSS), knowledge based DSS, executive information systems and business intelligence.

Personal DSS (PDSS) are small-scale systems that are normally developed for one decision maker, or a small number of independent decision maker, for one decision task. PDSS are the oldest form of DSS and they were the only form of DSS in practice. The two most widely implemented approaches for delivering decision support are Data-Driven and Model-Driven DSS (Alter, 1980). Data-Driven DSS help managers organize, retrieve, and synthesize large volumes of relevant data using database queries, OLAP (Online Analytical Processing) techniques, and data mining tools. Model-Driven DSS use formal representations of decision models and provide analytical support using the tools of decision analysis, optimization, stochastic modelling, simulation, statistics, and logic modelling.

One of the first definitions of Group Decision Support System (GDSS/GSS) was given by Desanctis and Gallup (Desanctis et al, 1985) as "an interactive computer-based system that facilitates the solution of unstructured problems by a set of decision-makers working together as a group." As combination of computers, communications and decision support technologies, GDSS facilitates a group of users to formulate and solve the unstructured problems. Due to the complexity of business relationships, the number of decision makers and organizations that are involved in decision process, large amount of external information source online accessible and the decreasing in the time allowed for decision making, the need for GDSS is greater than ever before (Adla, 2007). The supports that GDSS can provide during the group activity include idea generation (Hori, 1994; Tang et al, 2004) information sharing, decision analysis (Karacapilidis, 2000) and alternative evaluation (Choudhury et al, 2006). Among them various support tools are proposed such as brainstorming for idea generation, blackboard for information sharing, argumentation model for decision analysis and multiple-criteria decision model (AHP etc.) for alternative evaluation. In (Indiamma el al, 2008), team members' social parameters (trust, authority) are brought in to decision model for alternatives evaluation. In addition, according to different time/space characteristic of group activities, four environmental settings (including same-time and same place or different-time and different-place scenarios) are set allowing the GDSS design and other technologies to be compatible which can comprise: 1) decision room (synchronous, close proximity), 2)local decision networks(close proximity, asynchronous), 3) linked decision room (dispersed proximity, synchronous), and 4) remote decision networks(dispersed proximity, asynchronous) (Straub at el, 1988). In the early 1980s, GDSS research initially focused on 'decision rooms' (synchronous and face to face). Software to support group in these decision rooms include Mindsight, Facilitator, GroupSystem, and TeamFocus. Now GSS technologies and research have expanded to include all four categories of the time/space classification and include such sub-fields as Group Decision System (GDS), Electronic Meeting Systems (EMS), Computer Supported Cooperative Work (CSCW) and Computer Mediated Communication System (CMCS) (Arnott et al, 2005). Groups can communicate synchronously by face-to-face meeting, telephone calls and web-base 'chat rooms', or asynchronously by email, bulletin board system and Internet newsgroup. Nunamaker (Nunamaker et al, 1991) proposes a Framework for GSS research as Figure 2.2. It shows that the group decision making environment consists of a combination of characteristics of the group(including group history, member proximity, leadership behaviour etc.), the task (including type of task, level of decision-making, phases of decision-making, degree of task structure and time synchronization etc.), the group and organizational context (including corporate culture and behaviour norms, maturity of organization, organization size, reward system) and the system (EMS, CSCW, GSS).

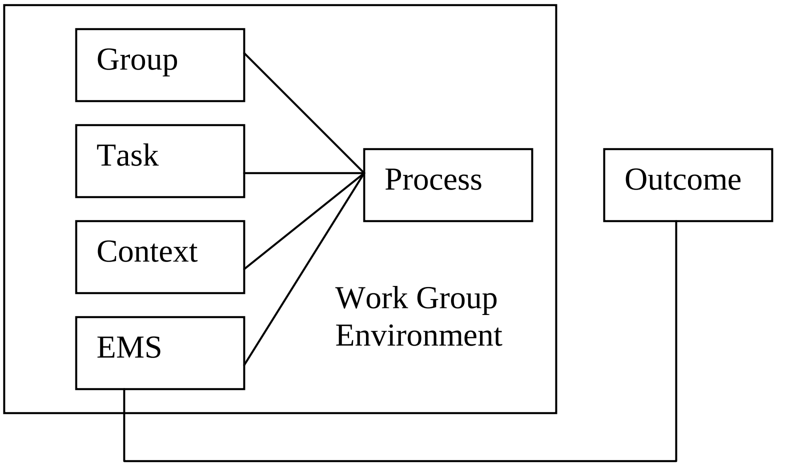

Figure 2.2 Framework for GSS Research

Negotiation support systems (NSS) also operate in a group context. But they have distinct characteristics compared with traditional GSS. As the name suggests they involve the application to facilitate negotiations. (Rangaswamy, 1997) As GSS were developed, the need to provide electronic support for groups involved in negotiation problems and processes evolved as a focused sub-branch of GSS with different conceptual foundatio*n*s. NSS has its conceptual foundations in game theory, which supports many models of bargaining (Krulwich, 1996; Chen et al, 2008), and social choice theory (Nurmi, 2001).

Artificial intelligence (AI) techniques have been applied to decision support and these systems are normally called intelligent DSS (IDSS) (Bidgoli, 1998) although the term knowledge-based DSS has also been used (Doukidis et al, 1989). IDSS include those that replace the model based management system with the rule-based Expert System (Wen et al, 2005), those that employ other intelligent decision making functionality such as neural networks, genetic algorithms and fuzzy logic(Tan et al, 2006), and those where the intelligent functionality is added to enhance the model based management system and improve user interface by using other parts of artificial intelligence including natural language processing or similar techniques (Lee et al, 2008).

2.3.2 Semantic Web Enhanced DSS

The semantic web is the migration from today's human readable, document based web to tomorrow's machine-readable data-based web. One view of the Semantic Web is that it is an attempt to integrate all of the world's knowledge (Sowa, 2001); the other view is that Semantic Web aims to represent the contents of web resources in formalisms that both programs and humans can understand (Corby et al, 2006). The core of the semantic web lies in the ability to express meaning and establish relationships between resources which includes documents, data and service and process based on the semantic meaning of concept and the relationship between them. In order to build the semantic web, four basic components have been outlined by (Frauenfelder, 2001): (1) machine readable markup for the content. (2) Tool enabling to read and index semantic markup. (3) Tools and services enabling to process semantic information and infer new facts. That can facilitate service-based sites ready to communicate with agent, not just humans. (4) Semantic agents enabling to reason and support decision making.

Ontology is defined as "the formal specification of concepts and relationships among the concepts" (Gruber, 1995). It has been commonly recognised as the core part of the development of

Semantic Web. In the DSS, system intends to provide the means for generating a series of decision alternatives for comparison and evaluation from different objectives. (Casey et al, 2002) has claimed that in order for DSS to better carry out their prescribed function, they will rely on formal representation to describe problem perspectives, decision objectives, context and constraints and therefore it will be ontology driven. He also claimed that there is a lack of research to develop ontologies and tools which can encode the semantic nature of decision making given logical criteria.

In the networked environment, the large amount of information could be dealt by DSS to analyse the factors of decision problem. Semantic Web technology allows agents to gather data based on ontological markup; filter it based on problem attributes and objectives, reasons; then put forward alternatives based on the decision maker's preference. The model supported by Semantic Web is consistent with the processes used by DSS namely intelligence, design and choice.

Niaraki et al. (2009) propose an ontology-based knowledge modelling technique using analytic hierarchical process (AHP) based decision making for a route planning system. The authors argue that insufficient criteria modelling for a personalised system is a major difficulty to make a route plan. The domain ontology can be exploited to develop the user and context model used for deciding better personalized travel route. This research shows that the semantic representation of domain knowledge can facilitate determination of the choice of criteria; but also domain ontology itself, organised by tree structure, can be easily converted to AHP decision model.

Supporting decision making has focused on helping to collect the relevant information and process numerical data, largely ignoring the central problem of tools to capture and assess validity of a heterogeneous set of facts and claims that bear on a decision. Chklovski et al. (2003) argue that the semantic web effort not only can semantically markup the argumentation for/against the important decisions, but also can rank information sources by collecting reusable semantic (reliability and trustworthiness) markup of the information from users.

2.4 Argumentation Support System (ASS)

An argumentation support system is a computer system to help users to make and manage their argument using predefined argumentation scheme and model during the process of interaction. In the existing argumentation support systems, the Toulmin model (Toulmin, 1958) and the IBIS model (Conklin et al, 1988) are widely applied. Those models try to logically structure users' argumentation by means of defining the role of participants' utterances and semantically rhetorical links between them, so that it can capture participants' deliberations during the problem solving and graphically present them in a formally defined structure (formalisation and visualisation), and better to discover the structure of the complex problem and trace the process of problem solving. In contrast to these models, Japanese researchers propose another argumentation support mechanism which emphasizes the transition procedure from participants' divergent thinking to convergent thinking in collaborative argumentation and it likely conforms to a human mental model (Sugimoto, 1998; Hori, 1994). An Augmented Informative Discussion Environment is developed to enhance and stimulate creative concept formation during the group discussion by means of clustering each individual's concepts with others' or existing concepts from a knowledge base. The links among the participates' mental model and the knowledge base can be easily explored to stimulate user to generate more creative concepts, which are particularly useful in new product design. In ScholOnto project, Shum (Shum et al, 2003) models collaborative argumentation in the scientific literature. Utilising IBIS-like ideas, scholarly argumentation regarding scientific claims within or among scientific papers are semantically annotated based on the pre-defined scholarly argumentation ontology. Searching and browsing services are provided to exploit the scientific argumentation collection in the intellectual understanding level rather than in keyword level. Hall for Workshop of metasynthesis engineering (Liu et al, 2007) is an implementation of metasynthesis approach, which integrates expert system, machine system and knowledge system into one platform. The essence of this implementation is that experts' wisdom are fused by the means of mutually enlightened and mutually stimulated argumentation supported by information technology, whilst knowledge and information from knowledge-base or even Web are also synthesized to achieve consensus about a problem. Most group argumentation systems as mentioned above mainly focus on discovering the structure of the problem, collaboratively learning and synthesizing different resource during a collective intelligent activity. These features are vital for the new decision support paradigm described above. However, due to different purposes of research, those systems lack of explicit decision making functionality.

2.5 Group Argumentation Based DSS

Group argumentation is a goal-oriented group activity, which can be run by group members posting their utterances iteratively to propose some idea/solution addressing the task, to express their positions and argue or complement those positions, to argue others' argumentation or justification and also to raise the critical questions to ask for clarification. In order to facilitate computer system to support users to make their argument and manage the argumentation information including navigation, searching or reuse, the argumentation support system has been presented to fulfil this task. In order to better achieve decision task in the context of group argumentation, decision support systems have been presented to analyse the agents' view, compare the weight and truthworth of the argument, resolve the conflict and finally reach the consensus.

2.5.1 Argumentation vs. Decision Making

The ultimate aim of decision making is to make a choice from the action candidates based on decision maker's preference models. In order to obtain a right decision, the different steps are often followed in the process of decision making: formulate and structure decision problem, design an evaluation model and obtain the decision candidate, and construct a recommendation. These steps can be implicit in the decision process. In the multi-criteria decision analysis, alternatives, criteria, decision maker's preference, its scale, and goal are main factors which need to be modelled by different tools to derive and aggregate the preference.

In comparison, in the context of argumentation the decision process is made explicit in term of different steps. Firstly, construct arguments in favour of and against each alternative (Amgoud et al, 2004); secondly, evaluate the strength of each argument, where it has been argued that the argument may have force of different strength (Sillince et al, 1994; Amgoud et al 2002); lastly compare the choices based on the quality of argument. Different aggregation procedures of argumentation have also been argued in the literature (Bonnefon et al, 2006). Apart from those steps, there are also some intermediate steps during the argument process such as defining the preference order among arguments depending on the perspectives.

More recently, in the field of artificial intelligence, argumentation has been put forward as a very general approach supporting different kinds of decision making. Decision makers do not only list pros and cons argumentation based on an alternatives, they exchange arguments, some of them interacting with others, attacking or enforcing previous arguments put forward. Some proposals have been proposed to clarify the connections between argumentation and decision-making and even handle decision-making in an argumentative framework. Among them, argumentation schemes for actions and value (Fox et al., 1997), for practical reasoning (Atkinson et al., 2006), and for multi-criteria decision making (Amgoud et al., 2005) are the most prominent ones. Those approaches share many similarities: firstly, consequences of the action are explicitly represented so that the evaluation is quite straight forward; secondly, they all explicitly define a neutral consequence so that intrinsic evaluation can be easily carried out based on comparison with this consequence; thirdly, they are all based on a predefined knowledge base and rely on the logic to represent the state of matters so that some action evaluation may be partial and also these approaches can only deal with one kind of decision making problems, namely choosing best solution".

In addition to argumentation schemes proposed in the field of artificial intelligence, implementation of argumentation for decision rationale support systems has been receiving great interest. Such systems address the needs of a user to interpret and reason about knowledge during a discourse. Instead of fully relying on the knowledge base, this kind of system handles the knowledge generated during the group interaction. For instance, QuestMap (Conklin et al, 1987) captures the key issues and ideas during group discussion and creates shared understanding in a knowledge team. All the messages, documents and reference knowledge are put on the whiteboard and interlinked by some well-defined relationship. The map style of the on-line conversation will lead to key decisions and plans. The aim of QuestMap is to capture the rationale of a design process which is based on the gIBIS hypertext group tool. Questions, options and criteria (QOC) is another model to represent the rationale of reasoning in a decision making process, in which it provide users a way to represent and integrate rationale at different levels in a design process. (Shum et al, 1993) Using this model in the process of the design, the questions are firstly raised to clarify the design task; the options are followed to provide the design solutions; at the same time the criteria are presented for evaluating the options in the context of the question. So the rationale of decision making in the design process are explicitly recorded and prone to be reviewed and evaluated. Finally, Belvedere, which was designed to support students engaged in critical discussion of science issues, uses a rich graphical language to represent different logical and rhetorical relation within the debate (Suthers et al, 1995). In conclusion, systems of this kind provide a cognitive argumentation environment that can externalize the rationale of participants and stimulate discussion among them; however they lack explicit decision making capability. From the decision process point of view (intelligence, design, and choice), these systems only well cover and model the intelligence process via rationale representation; but the design and choice process are not well supported in the system so that no recommendation and further decision analysis are presented to the decision makers.

In this section two different research trends of argumentation for decision making have been reviewed. The first one mainly focuses on development of the logical reasoning argumentation schemes, which results in choosing the best solution from the knowledge base. The second one more concentrates on capturing the rationale of the problem solving during the communication process, which aims to provide decision rationale support in the intelligent level. Although these two approaches explore different aspects of relation between argumentation and decision making, both of them are significant in the decision process.

2.5.2 Argumentation in Decision Support System

A decision is a determination of a course of action among possible choices reached after full consideration of all the relevant information. Thus, decision making should be supported by reasoning that will account for the characteristics of the different alternatives that are available. Argumentation based reasoning process support decision and the possible consideration against it, which provide all the elements necessary to understand the reasons behind a chosen or discarded alternatives. Decision Support System is a computer based system used to assist people in decision making. The need to introduce arguments in such systems has emerged from the demand to justify and to explain the choices and the recommendations provided by them. Argumentation in decision support systems can be classified into two different areas: multi-agent based argumentation for autonomous decision support and human based group argumentation for decision support.

In the context of multi-agent systems, regarding decision making, the interaction among agents is composed of presenting the reasons for and against a decision in order to persuade other agents to accept one's opinion. Sierra et al (1997) describe a general framework for negotiation in which agents exchange proposals backed by arguments with the case-based reasons why the proposal should be accepted. In Sycara (1990), a negotiation and mediation based conflict resolution framework – PERSUADER is developed. Persuasive argumentation as a mechanism for group problem solving of agents is introduced, in which agents can construct arguments by integrating case-based reasoning, graph search and approximate estimation of agent's utilities. In Neves et al. (2006), a multi-agent model to simulate group decision making is proposed in which the agents are designed with emotional properties, can reason with incomplete information and use persuasive argumentation to convince the other group elements about the best choice.

In the human based group argumentation system for decision support, the focus of the study is to develop an argumentation support system to facilitate the user to present their arguments towards the decision task and others' arguments and develop the argumentation based evaluation to analyse the argumentative information and group preference, handle uncertain and incomplete information and make group consensus for the group decision making. In this thesis, we mainly concentrate on the human based group argumentation for decision making support rather than multi-agent based argumentation for autonomous decision support. The detailed review about this field will be presented in section 2.5.3.

2.5.3 Overview on Argumentation Based GDM and DSS

Araujo et al (1995) propose a framework and protocol for group argumentation based decision making. In this framework, three essential steps for decision process (Intelligence, Design, and Choice) are well covered. The authors argue that the group discussion phase is a very important stage to recognise the problem and generate alternatives. In the decision phase, AHP decision model (Dyer, 1992) is used to determine the best alternative based on the group judgment whereas structurally recorded argumentative information are only used as reference material for a decision maker to evaluate alternatives. In this research, no automation mechanism is provided to process argumentative information to manipulate alternatives (such as update, evolution) and evaluate them. In addition, the authors also claim that argumentation information recorded in the good structure can be reused as a group memory to solve problem in the similar situation, but there is a lack of further discussion and implementation.

Karacapilidis et al (2000) describe an advanced Group Decision Support System based on cooperative argumentative discourse, namely HERMES System. HERMES system is a variant of the informal IBIS model of argumentation. In HERMES, each argument element has been well defined. Based on a defeasible reasoning mechanism, the state of the related elements can be dynamically modified while a new argument is inserted. A weighting mechanism is proposed to calculate the score of the alternatives so that the complete order of alternative can be obtained. Contrasted with the IBIS model, in HERMES “constrain” as a new argumentative element is introduced which provide a qualitative way to weigh reasons for and against the selection of a certain course of action. A constraint is a tuple with a format like (position, preference relation, position), where the preference relation can be “more (less) important than” or “equal importance to”. Argument toward constraints is regarded as a way to build the users’ preference model. It has been claimed that the system can be used for distributed, asynchronous or synchronous collaboration, allowing agents to communicate without constraints of time and space. Moreover, it supports defeasible and qualitative reasoning in the presence of ill-structured information.

Xiong (Xiong et al, 2008) propose a group argumentation system using a simplified Toulmin argument model, which consists of premise, warrant, modality, and claim etc., to represent group discussion information structure. In this model, “Modality” is designed as a quantitative scale that reflects the expert’s attitude to the claim, while premise and warrant are used to provide justification or evidence for experts’ views. Based on experts’ authorities and modality values of all argumentations towards a claim, the consensus value of claims can be computed. Although authors do not explicitly emphasize the decision support capability of their discussion information structure, it is obvious that the consensus building process in the system is very helpful for the group’s decision making. A higher consensus value that a claim gains means it is a decision more likely to be accepted by the group. However this discussion structure is constrained by one-round argumentation, where the expert is only able to propose the argument towards others’ claims but not able to further propose his opinion towards others’ argumentation. Multi-round argumentation will greatly increase the complexity of system and decision function, but it should be demanded in the factual group argumentation support system.

Indiramma et al (2008) argue that the most recent research works in decision making have addressed mainly computational issues, but social issues were given less interest. However in the group activity, the social issues such as trust, belief, empathy and emotions are very important factors. Authors propose a multi-agent based collaborative decision making framework in the distributed environment in which a group of agents collaborate for decision making based on expert trust. The computation of trust based on direct experience/social interaction is also described in detail. From various social parameters, some important information，such as certainty of information source and group consensus can be obtained, which are crucial parts of group decision making.

Amgoud (Amgoud et al, 2005) investigate the argumentation capability in the multiple criteria decision-making. They claim that by argumentation a user not only could be provided with a “good” choice, but also with the reasons underling this recommendation; on the other hand argumentation-based decision making is more akin with the way humans deliberate and finally make a choice. In the Amgoud’s paper, an argumentation-based framework is proposed in which arguments provide the pros and cons of the decision, which may be pervaded with uncertainty. The different force level of arguments makes it possible to compare pairs of arguments. The force of an argument is evaluated in terms of three elements: its certainty degree, the importance of the criterion to which it refers, and the dissatisfaction or satisfaction level of the decision regarding this criterion. Eventually, decisions can be compared using different principles on the basis of the strength of their relevant pros/cons arguments. The contribution of Amgoud’s research is to attempt to formalize an old idea of basing decisions on arguments pros and cons. In this research, the authors assume the evaluated valuation of three above mentioned elements has been predefined in knowledge base or explicitly provided by user and there is no provision of any mechanism to elicit those values. However in the context of the group discussion, the force of arguments should be recognized in group-wide, so it is necessary to have tools and a mechanism to obtain values of these elements.

Amgoud et al (2009) further distinguished two types of argument: i) epistemic arguments justifying beliefs and are themselves based only on beliefs, and ii) practical arguments justifying options and are built from both beliefs and preferences/goals. A practical argument may highlight either a positive feature of a candidate decision or a negative one; however an epistemic argument only proves the certainty of information (belief) in the related practical argument. In real argumentation, the practical argument is directly connected with the option (decision candidate) and the epistemic argument is connected with the practical argument or other epistemic argument. Generally, the strength of an epistemic argument will affect the strength of related practical argument, whereas the strength of a practical argument will decide the choice of decision candidate. The definition of these two types of arguments will have influence on the design of the decision function in the group argumentation context.

2.6 Issues in the Existing Research

Although the aforementioned research has covered different aspects to represent and evaluate argumentation for decision making purpose and even some argumentation based decision making systems have been developed, there is still not a clearly defined comprehensive conceptual group argumentation support system framework for decision making in which:

(i) Argumentative information can be structurally recorded and analysed for decision purposes. Argumentative elements should be semantically defined which enable the system to interpret the role of those elements so that system can provide automatic reasoning support to generate recommended decision from argumentative information. The semantically annotated argumentation information and argumentation process can be utilised to capture the decision makers’ decision rationale and also can be reused in other similar decision making contexts.

(ii) The profile of group members can be dynamically updated based on their performance which conversely will affect the reliability of individual’s argument. Social parameters are ignored in most related research. In group argumentation, the reliability of argumentation is greatly dependent upon the weight of the expert’s expertise in the relevant discourse. So dynamically modelling group members’ expertise is very significant.

(iii) The decision function and process based on argumentation should be well designed to facilitate automatic/semi-automatic decision making in the context of complex problems; the criteria for the evaluation should be elicited by the system.

(iv) Group mental space can be dynamically updated to reflect the current situation of problem solving. Most current research focuses on one-round problem solving which lacks a mechanism to structure and evolve the decision task. For the complex decision problem, in the course of the group argumentation new issues are raised and solutions are updated; task decomposition and solution iteration are required.

Technically the system based on this framework should be open, distributed and dynamic which can assure different information resources, models and users can be easily integrated together to generate solution, evolve solution and recommend the optimised solution to the decision makers.

2.7 Summary

Intelligence, Design and Choice have been identified as three important phases in the decision-making process. According to scalability and employed technology, decision support system can be classified into different categories and try to support some or all phases of decision making process. In classic decision theory, decision process often start with fixed actions and outcomes (criteria, preference) and a decision support tool can offer a solution to well established mathematically formulated problem but does little to support the whole decision process which includes representing the problem situation, formulating a problem and possibly constructing a reasonable recommendation. Furthermore, in ill-structured situations no decision process is clear-cut like fixed steps. Typically, these phases overlap and blend together.

Based on the multiple perspectives approach Courtney proposes a new DSS paradigm and mental model is in the heart of this process, where insight is gained and the mental models are updated while perspectives are developed. Rittel has identified that argumentation as an open ended, dialectic process of collaboratively defining and debating issue is a powerful way of discovering the structure of wicked problems and solving them. Many Group Argumentation Support systems have been developed to discover the structure of the problem, collaboratively learning and synthesizing different resources during a collective intelligent activity.

In another research trend of group argumentation systems, argumentation has been used as explanation or justification of action to evaluate the possible decision. The combination of group argumentation and a formal multi-criteria decision making model such as AHP has been reported. The theoretical argument based framework has been studied to distinguish different types of argument and evaluate the force of argument, which can provide theoretical support for the design of decision functions and choice of recommendation.

However there is still a lack of formal description about the conceptual framework of group argumentation support systems for decision making. In this chapter, some requirements have been specified. In order to support decision making in the context of group argumentation, argumentative information should be structurally recorded and semantically annotated for decision and analysis purposes, so the semantic enhanced argumentation information schema is required. In order to represent the certainty and reliability of each argument, the profile and expertise of group members should be represented and dynamically updated based on their performance which conversely will affect the weight of each individual's argument; in order to facilitate automatic/semi-automatic decision making, decision functions based on a well-defined argumentation information schema should be designed and an argumentation evaluation framework should be developed. In order to model the iteration of problem solving, there should be a mechanism to record and update the group mental space to reflect current situation of the problem which can be described as "what has been done" and "what needs to be done". Technically the system based on this framework should be open, distributed and dynamic which can assure different information resources and models can be easily integrated together to generate solutions, evolve solutions and recommend the optimised solution to the decision makers.