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Situation Awareness and Dynamic Group Formation of Agents and Humans Using Jabber

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Abstract: Developing a single summary function for situational awareness is challenging as it may in actuality involve a hierarchy of many domain specific groups with cross-domain interests. Accelerating and amplifying the decision process with decision support software may be brittle due to the inability of the software to adapt to changes and opportunities, such as new target types. Chat software has proven a vital tool for warfighters to communicate their situation and to assist each other in a free-form manner. Dynamic formation of groups or chat rooms using semi-structured summary functions allows decision support software to better assist the warfighter, and may improve their effectiveness. Jabber is an open architecture and standard XML protocol for instant messaging that allows XML protocol extensions and dynamic chat room formation. We discuss a mechanism for developing and decomposing situation awareness summary or utility functions that serves as a single disambiguated, semantically-tagged expression summarizing a focal subject. We then discuss methods for using Jabber to create chat rooms involving these focal subject expressions and for using Jabber to advertise and to discover situations and to utilize the chat room in a white board fashion so humans and Decision Support Systems (DSS) can work more effectively together.

1 INTRODUCTION

Evolving enemy tactics are eroding the effectiveness of existing methodologies, diminishing our ability to detect them, and muting the effects of efforts against them. Advances in methodology and technology are meant to provide agility to our forces to adapt to a fluid battlespace, amplify and recognize weak evidence, and react quickly to time-sensitive opportunities. A possible mitigating methodology is to dynamically create collaborative groups to analyze, decide, and act upon targets improving the overall efficacy of the warfighter. Collaborative technologies are an important aspect of net-centric warfare supported by the Global Information Grid (GIG), as exemplified in the ForceNet concept. One of the intents of these systems is to bring all resources to bear on a problem at the optimal moment. There are many formidable theoretical and technological barriers to this goal. For example, a typical terrorist tactic is to plan for or feign collateral damage [1] to garner sympathy and complicate planning and operations. The effects of such tactics are largely psychological with culturally specific meanings, involving many parties not commonly in the military process, and occurring over timescales of days and months. Many of these factors are difficult or impossible to render in formal analysis, procedure, and mechanistic reasoning, thereby making human understanding a necessary component in dealing with these situations. Enemies are getting better at disguising their goals and obfuscating their trails to ensure their adversary is forced to reason under incomplete and uncertain information.

However, many of the more traditional and formal methodologies are still very effective against a wide spectrum of our adversaries, and so a mixture of

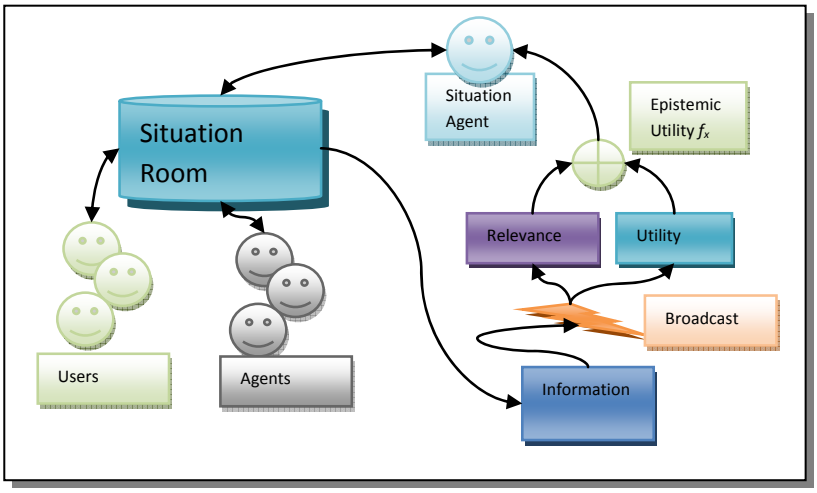
procedural/formal and dynamic/semi-formal methodologies will likely be most effective. Dynamically forming groups of humans and automated reasoning in real-time online collaboration (RTOC) can be a force multiplier through efficient leveraging of knowledge and capabilities and by task/resource allocation in a question/answer decision support process. Forming optimal groups and allocating tasks/resources is a difficult task even with fairly complete and certain knowledge. Dynamically forming groups from contextual information relaxes some of these constraints, but depends on greater knowledge, training, and latitude for control at lower echelons. Real-time online communications and Lightweight Collaborative Whiteboards (LWC) have proven effective [2, 3] in increasing situational awareness (SA), but dynamically forming membership criteria for groups in these systems is still an open problem. This paper focuses on a system and method for determining group membership of agents and humans in the framework of a common open source XML chat environment (Jabber/XMPP). Jabber is finding increasing support in military applications explicitly through standards [4] and through common usage [5], and has been used in joint exercises. We propose that discovering a membership function based on opinion contribution decomposition can be used to determine an approximate membership. Assisting the formation, management, and efficacy of groups by relevance function discovery will be referred to as *epistemic dynamic group formation*. Here we present some of our research on the system and methodology within the framework of real-time collaboration using Jabber for situation awareness in defense applications.

2 Collaboration and Group Formation

2.1 Utility and Group Membership

There are many well-known mechanisms for creating groups based on resource allocation algorithms and adaptive middleware [6, 7]. These algorithms often require a *utility* function or method of determining value and contribution of people and resources towards some goal. Even reactive learning or resource allocation systems require prediction of *value* (or worth) to determine the best allocation of resources [7]. Utility theory has historically been used in economic and game theory settings, but these also usually work either in large statistical settings or tractable and unchanging classes of goals. It is very difficult to dynamically devise a single utility function according to context that can determine goal satisfaction. One mechanism to determine membership in the group is to form a summary function yielding a measure of relevance of the resource (person, file, message, etc.) to the *intent* of the group. Since it is unlikely that the exact formulation of this type of function will be completely automated in the near future, it will be necessary to approximate it. Human authorities (and to a limited extent, software agents) can render opinions on how relevant an element is to a goal. Humans are often called upon to render an opinion according to policy, which makes the opinion canonical regardless whether automated systems could produce a like opinion. We could approximate the desired relevance function by asking each authority in the group for an opinion regarding group membership for the element in question, and then combining these opinions to arrive at a consensus about group membership. The consensus mechanism will need the ability to fuse or summarize membership opinions from humans and

algorithms (e.g. agents). Belief calculus is used in belief theory and *epistemic* (or opinion-based) logic to provide the operations necessary to fuse opinions and produce relevance values. We use belief calculus with answer sets in a similar fashion in our Hybrid Intrinsic Cellular Inference Network (HICIN)[1] product [8] to fuse inputs from humans and mechanistic reasoning and create a semantically-tagged opinion space. Rules and facts relating these semantically-tagged opinion spaces are then unified in a uniform proposition space. Thus, HICIN uses belief calculus as a unification method to correlate multiple hybrid inputs and generate opinions about them. Similarly, we intend to apply belief calculus here for dynamic group relevancy opinion unification.



Determining that an element has *meaning* (relevance) with regards to a group does not necessarily inform us about the elements *value* or *utility* to the room. Aside from relevance, an element may have varying values of belief in addition to contribution (or atomicity) to the dynamic group as well. In military contexts, the value of an element is considered in terms of its effects or contribution to net effect. Thus there are three parameters that participate in the decomposition of an element's final contribution to a group: relevance, belief, and value. Relevance and valuation are related to the intent of the group, and so it is important to understand and qualify intent when building collaborative groups in military contexts.

The decomposition we are aiming at is at the consensus level between humans and agents, not initially explicitly at implementation concerns with human parameters such as cognitive load and agent parameters such as negotiation, etc. These parameters are contextual and should be discovered through the decomposition process only, and then only as far as they are related to *epistemic* (relevance and the use of epistemic logic) and *utility* (worth and contribution). The construct used in Jabber-style applications is called a multi-user chat (MUC) room. We propose extending the concept of these MUC rooms to include a one-to-one relation with an *epistemic-utility membership function*. We will refer to the combination of a MUC room and the software agent that mages it using an *epistemic-utility membership function* as a ***situation chat room***. These *situation chat rooms* allow information necessary for situational awareness to be directed to the room when meeting the minimum sufficiency of the *epistemic-utility membership function*. The concept of

[1] HICIN is funded in part by an Office of Naval Research (ONR) Small Business Innovative Research Transition program (STTR) in collaboration with University of Nebraska at Omaha.

this function is related to deriving objective functions for intelligent agent software. Because there will be rules and a working set associated with the *situation room* in addition to the *epistemic-utility function*, it would be fair to think of the chat room supervisory system as a kind of *situation agent*.

3 COLLABORATION IN DEFENSE

Collaboration is an important component in the evolving net-centric warfare (NCW) architecture in defense systems, such as the GIG [2]. When increasing the efficacy of the war fighter via situation awareness (SA), operational context (OpContext) and dynamic group formation is an integral and growing part of defense methodology. In NCW, communities of practice (CoP, not to be confused with Common Operational Picture, COP) form around specific focus tasks supporting a commander's intent (CI) in a common community of action (CoA, not to be confused with Course of Action, COA) [2]. There are differing types of groups based on intent or function and methods of collaboration and their operational context [9]. Situation awareness has been called a mix of art (intuition) and science (gizmos) [10], and the consensus of opinions from humans (intuition) and agents (gizmos) reflects this.

Knowledge of the enemy, battlefield methodology, and military technology will change through time and so it would be more ideal to find slow changing designs with a longer shelf life, rather than attempting to decompose knowledge in subject domains that are likely to change. Knowledge management is an important concept throughout defense and is meant to help acquire and transform knowledge to increase the effectiveness of the warfighter. Acquiring and decomposing knowledge domains is a never-ending task, and predicating a design on fixed high resolution knowledge models will surely slow the delivery of technology to the war fighter and still has no guarantee of applicability when deployed. Instead, a methodology that is opportunistic in usage of knowledge models and emphasizes the ability of the warfighter to adapt to dynamic situations has a better chance of increasing the warfighter effectiveness earlier and better. This implies that information is acquired, shared, and transformed into knowledge with humans and machines working together.

In 2004, the U.S. Department of Defense (DoD) Chief Information Officer (CIO) published DoD directive 8320.2, "Data Sharing in a Net-Centric Department of Defense" with the following summary points [10]:

1. Ensure information is available to the decision maker, when needed.
2. Ensure information is discoverable, with appropriate tagging.
3. Ensure information is sharable in public spaces, when possible.
4. Ensure information is broadcast-able, which enables "many-to-many" exchanges.

We will discuss how our proposed *situation chat room* methodology supports these points and pushes forward the net-centric vision.

3.1 Situation Groups

The first point is hinged on the concept of *need*, which can be interpreted as having a utility and relevance to a group of decision makers. These decision makers can be summarized together as a *situation group,* which is a group of users associated with a *situation chat room.* Each room has an associated *epistemic-utility* function for determining utility and relevance of information to the intention of the room. The function is a proxy for the needs of the decision maker, and can be used as a passive filter and/or an active gatherer (recruiter). When acting as a passive filter, the function determines whether information makes it to the decision maker. This is an outer level of information reduction and cognitive management, and further cognitive management is highly likely to be domain-specific and so must be done by the domain-specific visualization and further processing. A discussion of full active gathering of information is beyond the scope of this paper, but it will likely include mobile agents, network group multicast address management, publish/subscribe, etc.

3.2 Tagging and Discovery

In the second point, meta-tagging information is more complex than it may sound. There is really no sure way to make certain that a set of tags have the same *semantic* meaning across all users and situations. Meta-tagging often implies that the tag has some inherent meaning, or participates in a larger set of relationships (often called ontology). The value of a meta-tag is often in the relationships it has with other meta-tags, which is one reason graph analysis is so important to semantic analysis. However, meta-tags perhaps aren't strictly always required as there is an implied typing by association. When an element is a member of a group, the typing or tagging of the group can be inferred to apply to some degree to the elements in the group. The typing implied by the group may evolve through time according to some larger behavior or context, without inventing new tags and applying them to elements. Group membership queries on an element can identify the meaning of the element and serve the same function as applying semantic tags to that element. Our group membership mechanism maps well to net-centric publish and subscribe methodology and makes more sense for a military context where situations are fluid. Thus, the elements participating in a set of *situation rooms,* assume the larger meaning of the set of rooms they are in. This can provide a richer and more flexible mechanism for inferring meaning than a set of ontology-specific (and often arbitrary) tags. Of course, since Jabber/XMPP is an XML-based system, the capability of meta-tags always exists on the elements themselves and could be used in membership functions.

3.3 Information Sharing Spaces

Sharing information depends on addressing (or keying) shared knowledge and access management. Finding and sharing viable resource addresses depends on the tagging and discoverability, discussed earlier. Not all resources are small files, and information sharing may entail accessing large streams of data (such as video) or require complex access methods (such as databases). Public sharing of information thus depends on making sure that public resource addressing is accessible and will successfully provide the referenced information for the widest possible audience.

There are specifications and systems for Uniform Resource Locator (URL) and Uniform Resource Identifier (URI) redirection and proxies that can convert complex resource addresses (URL or URI) to resolved and accessible resource addresses for use in systems like the U.S. Defense Information Systems Agency (DISA) net-centric enterprise services (NCES) content staging service.

It is also important that address resolution take into account context of the requester. This is important because bandwidth may be restricted, such as in forward deployed situations, and resolving to local and/or compressed formats can drastically reduce bandwidth usage. If a compressed resource (such as a 100 KB terrain image) meets the *need* of the *situation room*, there is little use in sending a much larger resource (such as a 10 MB terrain image). Using context specific resource address (URI or URL) resolution can have many-fold savings on bandwidth (such as the 100-fold reduction in the terrain image example), but this requires that the *need* of the requester is somehow encoded in the resource address request. There are many specifications for dynamic resource sharing and address resolution, but *utility* is still an open problem with implementation of these systems. Further complications arise when commanders make important decisions in response to this shared information (or evidence). Often, the justification of the decision requires that the evidence used is accessible at a later time in the state it was when the decision was made. The *need* for the resource and the *logging* of the access to the resource are time and context sensitive.

Situation rooms contain a representation of the *need* (and relevance in the form of the *epistemic-utility function*) of the decision making group, and are capable of managing time stamped logs of all resource registration and resolution. This provides a suitable interface for employing persistence layers (to maintain persistent stores of evidence such as resources, logs of discussions, actions, and decisions made for correlation (such as after action reports) with other systems. Current chat systems in general have logging and associated storage, allowing history of messages and retrieval of room specific resources. MUC *situation room* management provides a mechanism for associating information on more than (possibly arbitrary) tags, and allows searching and retrieval of information *within the context* of usage. The usage of the information within this context allows inferred windows of associative tagging. An enormous number of standard (ontology-based) tags would be required to mimic this flexibility.

3.4 Many-to-Many Communications

Many-to-many and dynamic federated communications is an important aspect of net-centric warfare and the 'power-to-the-edge' concept. Delivering the right information to the right person at the right time means that barriers to communications must be overcome. Determining who the right person is depends to a large extent on the role and context of the person. These roles and contexts can be characterized by the kinds of communications the person is involved in. When a person is allowed to join a *situation room*, that person's role and contribution to the group will be determined. To deliver the right message to the right user, from a computer science point of view, means that the *type* of the message is unified with

the *type* of the person, at some level. There then must be a mechanism to derive equivalence of *type* between the message and the person.

Developing message-person type equivalence is a difficult problem because automated message tagging will likely not be able to handle the very large differences in message and person types. To allow for scalability, message type translation to person types must be performed at the network layer, and will likely only provide approximate typing. This will create groups relating messages to persons which are roughly like message routes from source to destination. These route groups may be very large, depending on the quality of approximating message type to user type. Multicast communications allows route groups to be developed by the networking system itself, and the field of study was developed to address problems like this. These approximate route groups can be designated as multicast groups which direct how messages are routed on the network.

Routing and distributed multicast resource management is a problem that has been pursued in military networking systems for many years [7]. Leveraging these systems at the GIG/NCES level will facilitate deployment and efficient use of network resources. As the class of GIG/NCES systems evolve, network systems will be able to discover and negotiate utility/worth services (e.g. SOA utility service) that can assist in assigning value to resources. Such services can be used in rigorous resource allocation algorithms and in developing and assigning multicast group addresses. Chat systems (and other real-time online communications system) are generally packet- or datagram-based and are therefore amenable to broadcast or multicast communication structures. *Situation rooms* are structured and partitioned using *epistemic-utility functions* that may be aligned with services supporting network resource allocation systems. There is equivalence between criteria and mechanisms used in developing message-person routing groups and the network resource grouping. There is, therefore, an equivalence between a MUC *situation room* and a multicast group address, such as the Internet Group Management Protocol (IGMP) address or another group management scheme. While the specifics of such mapping is well beyond this research, the concept of situation rooms will fully support multicast address mapping at the network level.

Besides the natural many-to-many communications inherent in multi-user chat systems, chat servers also have the ability to form federations with other chat servers. *Situation agents* may route messages between rooms by joining multiple rooms with supporting goals and act as a *semantic router* between the individual *situation rooms. Situation agents* may work with the Jabber servers and other collaborative gateway software in translating dynamic group formation criteria into chat room assignments. There are some factors in creating dynamic groups that rely on the underlying communications network. For example, where the chat server is located on the network may affect the overall latencies and security considerations. The nature of multi-user chat room creation and configuration, though, is meant to support widely dispersed users with possibly long (greater than several seconds) latencies and network topologies.

4 GROUP FORMATION CRITERIA

A common aspect of agents is the ability to participate in a question and answer process or chat session. HICIN, for example, has a chat capability to participate in real-time online communications and can act as administrator in dynamic group formation. We are exploring using epistemic logic in forming relevance functions which can provide criteria tests for membership in dynamic group formation. Real-time online communications systems, such as the open source extensible messaging and presence protocol (XMPP), used in Jabber, provide the necessary room creation and management functions and can be used with Epistemic summary functions to create and manage dynamic real-time situation rooms. There is an overall need in the modern military for *exchanging knowledge for mass*. This can roughly translate to time-limited optimization of maximal usage of the human and physical resources at the commander's disposal. Interpreting the commander's intent in determining how to best group and apply resources can be approximated by group formation algorithms that consider the utility of human and agent resources to the intent/mission.

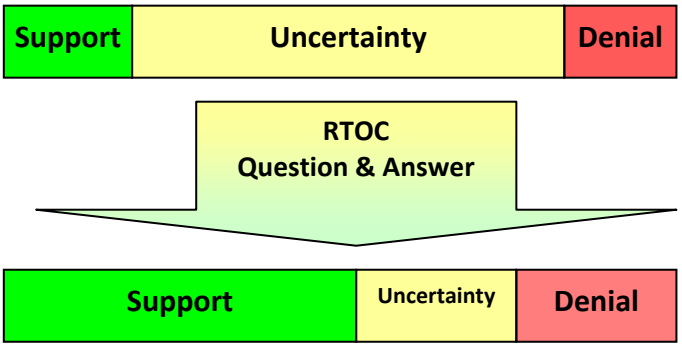
When criteria for group formation can be represented in a machine readable form, then automated systems can assist in developing group criteria and metrics. Dynamic collaboration assists in evaluating developing situations that don't map well to existing methodologies, or the so-called "weak requirements" or asymmetric warfare problem. Even if the target signatures are well-defined and easy to disambiguate, determining which targets are actionable may be difficult. A dynamic group, with humans and agents collaborating, is much better equipped to quickly decide on a protocol and define a way forward, even in the face of limited or uncertain evidence. Group collaboration may also assist in evidence evaluation, especially for higher-level patterns such as human behavior where automated reasoning traditionally performs poorly in general. So developing criteria of sufficiency for requirements or evidence may be helpful in determining group formation.

Distributed groups also assist in exchanging of knowledge for mass, by reducing the footprint of people requiring physical deployment. Being able to reach a wide array of subject matter experts (SME) and form a panel to address an emerging problem will increase the effectiveness of the response, as well as reduce the response time. NCW capability allows for this free form group formation, but does not provide all the mechanisms for determining group membership. So developing criteria for related SME knowledge and minimum SME domain requirements may be helpful. Leveraging criteria on factors such as insufficient requirements and SME aren't enough to provide the best partitions of people and resources.

4.1 Strategic Goals and Local Reality

RTOC as a tool should support *commander's intent* and assist in ensuring the "golden thread" of intent is maintained throughout the process. This is a very difficult, open research task, as was highlighted at the Phoenix Challenge 2007 Information Operations Conference. Strategic goals are interpreted through the command hierarchy and should guide the dynamic group formation and be a factor in generating a utility or valuation function. When *local reality* is dissonant with this intent, it may become a major driving force in determining when new groups need to be formed to deal with the dissonant reality. There is, of course, no way to determine how dissonant local reality is going to be with the original intent. It may be that the original intent is not achievable regardless of the investment of blood and treasure. We need to be able to determine how much of this reality supports the intent and how much denies the intent of the dynamic groups criteria.

RTOC is a form of a question and answer process, and so it is also a form of decision support. We can assume that in the beginning of the group formation there is some amount of evidential support both for and against the current intent of the *situation room*. There will always be some amount of uncertainty, as well. As the group exchanges information, the amount of uncertainty with regards to the goal or intent of the room should begin to diminish, up to some constant. It is unlikely that the uncertainty will converge to zero, as certainty and relevance of evidence have a natural decay, and this also applies to evidence of support and denial. A more formal analysis of the intent poses the intent as a hypothesis against which the *situation room* engages in evidence to support or deny the belief in the hypothesis. This is a form of evidential reasoning, similar to what we use in HICIN when forming belief functions to fuse disparate and hybrid data. Representing the goal of the room as an evidential hypothesis can thus be approximated with evidential reasoning networks (ERN).



5 Situation Awareness

Increasing SA is a desired capability in dynamic collaborative groups. There are many different interpretations of situation awareness, however, such as concept,

conversation, group, informal, peripheral, social, task, and workspace [11]. Jabber supports additional communications and visualizations via its flexible XML-based protocol, and so many types of SA can be approximated both through stand-alone applications with specialized visualization, as well as with web embedded Jabber communications, leveraging XML and other formats such as SVG for vector graphics, and X3D for 3D models and simulation [11,12]. However, textual communication can be just as dense and sometimes more appropriate than other media-rich communications. For example, certain kinds of situation awareness (uncertain threat, for instance) are notoriously difficult to communicate with 2D/3D models and other common forms visual presences. Natural language, such as speech and free text may convey a better picture and more information than other forms of communications. This is especially true with descriptions about uncertain concepts and behaviors, where natural language performs better than predominantly geo-spatially-based visualizations.

5.1 Hedges and Uncertainty in Natural Language

Humans often communicate very important yet uncertain information using hedges. It is easy and natural for humans to use hedges and analogies to expedite communications, and computers have a difficult time interpreting and using this information. Hedges and communicating uncertain information is a typical problem in natural language processing. Intelligence analysts often use hedges when communicating uncertain information. A study by Steven Rieber of the Office of the Director of National Intelligence discovered that terms like "possibly" or "we believe" can have wide variation between analysts. One of the benefits of using a *situation room* implemented with evidential reasoning and epistemic logic is that these terms can be normalized to specific belief statements, represented in appropriate data structures, and communicated between the users in the group, so that group expectations of hedge meaning and use can be discovered quickly. There are some existing standards, such as Sherman Kent's hedge normalization, given in this table. Beyond the standardization of hedges, communicating uncertain information is important in learning new information.

Percent	Tolerance	Hedge
100%	0%	Certainty
93%	6%	Almost Certain
75%	12%	Probable
50%	10%	Chances About Even
30%	10%	Probably Not
7%	5%	Almost Certainly Not
0%	0%	Impossibility

5.2 Situation Awareness Group Dynamics

Group decision making may produce better results than decision making in a vacuum, and it is likely difficult to avoid interdependencies that arise in real-world decision making. In developing models of situation awareness, group dynamics will thus play a significant part and may prove to contribute heavily to limiting factors where team interactions are involved. One of the important features of free form communications in RTOC applications is learning and exchanging objects in the user's environments. Understanding and tracking referential structures has been shown to be important in understanding free-form human interaction in chat sessions [12]. Here is an example of a notional *situation room* log of communications for an

information operations mission, here called "*Golden Spike*". The mission is to inject network inspection software into an adversary's router. This mission and *situation room* log is meant to demonstrate how natural language can be important to situation awareness, and how a *situation room agent* can play an important role in mission success. There are three members in the *situation room* which are the leader (G*olden Spike Leader),* the field operative (*Hammer*), and the *situation room agent* (*Golden Spike Agent)*. During this mission, geographic location of the field operative is maintained in their presence information, and a software agent tracks this location. Verbal descriptions of the target equipment are analyzed, and actions are recommended by the leader. Determining the exact profile of the equipment requires a security upgrade of the room, which the leader accepts. The room agent identifies the equipment and the leader tells the software agent (via the "@" symbol) to send software to the field operative to inject into the network router. The software agent initiates testing, and field operative is instructed to clear the target environment upon success.

```
Golden Spike Agent> 'Hammer' is within 10 meters of the 'target'.
Golden Spike Leader> can you see the equipment?
Hammer> i see it but it appears to be chinese clone
Hammer> it says its series 7606
Golden Spike Agent> 'target equipment' may be 'Cisco 7606'
Golden Spike Leader> use your termjack
Hammer> it says i505-D35
Golden Spike Agent> termjack classification requires secure access.
Golden Spike Agent> 'Golden Spike Leader' has granted access.
Golden Spike Agent> 'i505-D35' indicates target equipment is 'Cisco 7505'
with 'IOS 12.1(5)XM4'
Golden Spike Leader> @send root kit
Golden Spike Agent> Sending 'Cisco 7505, 12.1 access kit' to 'Hammer'.
Hammer> ack, ready injection
Golden Spike Leader> initiating sentinel
Hammer> ack, injection green
Golden Spike Agent> ICMP packet traffic confirmed.
Golden Spike Leader> clear the target
Hammer> ack
```

Notional Golden Spike Mission Log

5.3 Chat and Messaging Software

Wide adoption of net-centric standards, such as Jabber, forces network technology implementers to consider ways of integrating these substrates [13]. As SA technology and methodology evolves, *situation rooms* and natural language processing may begin to play an important role in assisting network topology and routing software in optimizing network traffic and quality of service parameters. The value density of natural language will likely not diminish in the future, and so developing *situation room*-type technology may help reduce network bandwidth requirements in net-centric applications and the GIG.

6 Semantics of Collaboration

6.1 Semantic Portals

Relating groups of people and resources by semantic groups is one of the principals of semantic portals. Semantic portals [14] relate elements by an underlying ontology and can use various membership functions related to this ontology. Some ontology structures admit a semantic distance function, and resources and people within

relevance thresholds may be included. Using normalized ontology for service discovery and interaction is also a component of GIG-related architectures [15]. Unfortunately, many of the concepts and so-called semantic distance functions may not admit rigorous enough distance functions to support concept density metrics as predicated by some situation assessment measures [16].

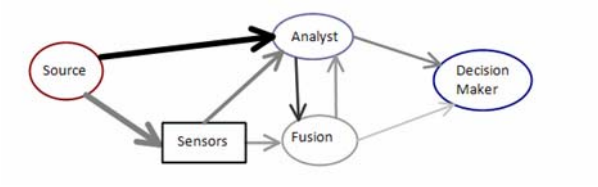


Figure 1 Evidential Paths

Ontology-base technologies are an important glue allowing services to discover each other and the required resources without strong coupling to some brittle framework. This power comes with complexity in system architecture and sophistication in modeling [14]. The epistemic group formation model is predicated on some form of concept labeling and ontology inter-operation for discovering and utilizing resources within the context of a situation awareness room. Knowledge representation (KR) and ontology are vital epistemological tools in decomposing the problem space and forming the necessary concept labeling structures. Fluid environment and dynamic requirements means that it is extremely unlikely a single universal ontology is possible, and so situation rooms must be able to approximate ontology development as the situation develops, integrating knowledge and word usage dynamically from the situation rooms context.

6.2 Ontology vs. Folksonomy

Developing full ontology interoperation is likely intractable and can become a barrier to learning in novel situations. Semi-controlled vocabularies (sometimes called *collabularies* or *folksonomies* [17]) provide a flexible lexicon that can better describe dynamic situations and clashes of culture. New words and word usage provides an insight into cultural meanings, and may reflect the efficiency of natural language when describing new situations. Information operations and psychological operations (PSYOPS) require learning new concepts and vocabularies to project a feeling of belonging and economic expression of strategic relationships. Thus, a collaboration system, which is rigorous enough to manage group formation, yet open enough to morph as language evolves, is preferable to a purely mechanistic ontology-based system.

7 EPISTEMIC LOGIC

Epistemic utility of the *situation room* must preserve the property of rules and utility of the mission. *Situation rooms* may express their structure in terms of a propositional logic. Epistemic logic is related to modal logic, and addresses belief formation, propagation, and evidential reasoning. Epistemic logic has been used in agent-based designs for many years, in part because it addresses shared knowledge and agent collaboration [18]. In our methodology, we use epistemic logic supported by n belief calculus capable of representing and reasoning with uncertain information, such as hedges.

7.1 Belief Calculus

A belief calculus such as *Subjective Logic* (SL) [19] provides a set of operators for expressing and manipulating belief statements by some authority (or subject) about some object. The belief statement, or *opinion* in SL, is represented as $\omega_{object}^{subject}$. The belief statement should maintain the same representation and connotation throughout a given reasoning trace. While belief calculus operators may have domain-specific variations, the initial belief set and thresholds must maintain inertia of meaning [20] throughout.

A belief calculus provides a mechanism for smoothing ranking while providing a bridge to belief mass assignments over specific focus elements in the frame of discourse, Θ. The structuring of the belief frame can be optimized to preserve measure (epistemic) information. Then discounting mechanisms would allow smoothing beliefs on focused measures to be weighted according to epistemic factors, such as contextual relevance. Some of these belief operators are forms of geometric projections, which may vary according to a domain-specific topology. A fundamental property of the belief calculus is the ability to summarize or combine belief statements from two separate subjects (authorities) α and β on the same object *p*, $\omega_p^{\alpha} \oplus \omega_p^{\beta} = \omega_p^{\alpha \circ \beta}$. The *consensus* operator expects object equivalence and the resultant summary belief statement maintains structure and meaning. There is an (implicit or explicit) appeal to embedding the belief statement in a set of belief frames providing guarantees towards object equivalence. When a belief statement is considered not completely aligned or relevant, it may be discounted by the *discount* operator, $\omega_{\theta}^{\alpha} \otimes \omega_p^{\theta} = \omega_p^{\alpha:\theta}$. Given authorities α and β, an egocentric or agent-relativized belief about object *p* may be expressed by discounting the other agent's belief before combining it with the local belief consensus, $\omega_p^{\alpha} \oplus (\omega_{\beta}^{\alpha} \otimes \omega_p^{\beta}) = \omega_p^{\alpha} \oplus \omega_p^{\alpha:\beta} = \omega_p^{\alpha \circ (\alpha:\beta)}$.

7.2 Group Membership as Trust Networks

For each situation room, only some members may provide meaningful input or have expected behavior according goal of the room. The representation of these group members may done through the use of a trust network [21], where trust is a belief between members based on functional, direct, and indirect trust relationships. Trust networks represent a form of group membership summary functions for determining fitness of the room or dynamic group based on a set of members.

The trust between group members as well as relevance of a member to the group may be deduced from semantic relevance measures. For example, an agent β may claim relevance in some group θ, $\beta(\theta)$, and agent α may discount the claim by β, $\omega_{\beta(\theta)}^{\alpha}$. By discounting β with respect to group θ, agent α may derive relative trust in β for group θ, $\omega_{\beta(\theta)}^{\alpha} \otimes \omega_{\beta}^{\beta(\theta)} = \omega_{\beta}^{\alpha:\beta(\theta)}$. Entailing and representing the dynamic group specific trust is a mechanism for forming trust networks and dynamic group membership.

To build trust networks, the belief frames are driven by the problem statement and are used to build the epistemic structure for fusing disparate belief statements from trusted opinion makers. Determining atomicity, contribution, and/or weighting is also a difficult domain-specific task that has dramatic effects. The contribution weights can also change according to aggregation and currently known facts and so can be highly sensitive to state or sequence. Not all domains have well-behaved semantic distance measures and so producing a bipolar belief statement tuple allows "best guess" distance measures (both for, against, and indifferent) that can be interpreted in a domain-specific way. Fail-safe interpretation of uncertainty towards either belief or disbelief (like the possibility of a bomb in an airplane) can be limited to specific concepts and associated reasoners or agents. An agent in a situation room can be viewed as participating in distributed reasoning [22]. An epistemic summary function using belief calculus is meant to specifically support integrating a wide variation of agent models including humans in the loop.

The belief calculus method, to some extent, supports normalization of agent and human reasoning traces when the belief statement is viewed as a typed process sample, represented by a unity interval division made by a hypercomputing process (e.g. human) [23]. Net-centric multi-agent models are evolving to include discoverable web services. Discovering and integrating web-based agents into an agent trust network may benefit from negotiating a small set of belief frames around the granularity of the web services [24]. The pre- and post-structure of causal networks may align with those of a remote procedure call, such as the invocation of a web service.

8 Valuation and Risk in Situation Rooms

Situation rooms represent a one-to-one correspondence between focused situation measure functions and the intent and structure of the situation rooms. The hypothesis of the *situation room* has an associated belief statement at any time that can be used in interpreting the expected value of the hypothesis, and thus the "state" of the *situation room*. The situation room may, for example, be considered to have achieved its objective if the belief value exceeds a threshold based on current rules of engagement (ROE).

8.1 Effects, Valuation, and Epistemic Group Membership

Groups formed along the lines of valuations, such as quantifiable concepts like cost, assets, and risk, may have their membership functions interpreted as valuation or utility functions. Belief calculus has been used in threat valuation models [25], and the basic theoretic frame is related to other multi-criteria decision making. Each agent in the multi-agent system (MAS) may have a different way of decomposing effects and interpretations of valuation. The mechanism for determining impact value may be dependent on the causal agent and the mechanisms that will bring about the impact. One way to represent effects-based reasoning is to develop a threat, vulnerability, and asset value (TVA) model [25]. Only some combinations of threats and vulnerabilities are sensible, and belief in the consequent risk is the conjunction of the belief in the threat and vulnerability antecedents:

$$(r_{t\wedge v}, \omega_{t\wedge v} = \omega_t \cdot \omega_v) \leftarrow (t, \omega_t) \wedge (v, \omega_v) \qquad (1)$$

For the resultant risk belief to be useful in calculating asset risk, the belief calculus should support the interpretation of the risk as expectation:

$$AssetRisk = Ar_{t \wedge v} \cdot E(\omega_{t \wedge v}) \qquad (2)$$

Further discounting risks by relevance may help bound the causal chain in exploring the antecedents to risk implications. Thus, *situation room* constructs can also be used for estimating asset risk, especially in situations involving weak evidence or asymmetric threats.

9 Conclusions

Real-time online communications is becoming an integral part of the warfighters toolset. It can assist the warfighter by facilitating situation refinement, but it needs a mechanism for integrating mechanized and authoritative reasoning in semi-structured format. Because of the complexity of induction and the impact of weak or complex evidence, it may be that most or all evidential sources must (at some level) support a generalized chat model, where semi-structured or textual information is communicated between humans with little translation. This is to reduce the chance of mechanized reasoning culling weak, but high impact evidence, and thereby reducing the efficacy of the warfighter. Iterative decomposition of situation rooms can provide a mechanism for examining the evidence from the sources as a sensor level whiteboard. This decomposition provides a fusion model, where mechanistic reasoning systems such as agents and fusion systems can participate with human counterparts in summarizing and classifying evidence. As mechanistic reasoning and fusion systems evolve, the number of participating humans in *situation rooms* may decrease, while still allowing human intervention under specific conditions. It appears likely that real-time online communications and chat systems will continue to evolve and have more utilization in military operations. Focused semiotic functions based on belief calculus admit a multi-resolution approach that can guide situation decomposition into semantically cohesive *situation rooms*. These rooms provide an excellent basis for distributed situation queries and dynamic group formation, which can provide a whiteboard for the integration of human and mechanistic reasoning.

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