Providing Insight into Command Post Operations Through Sharable Contextualized Net-Centric Visualizations & Analysis

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Since April 2004, the Command Post of the Future (CPOF) has been deployed and utilized in Iraq. This innovative C2 system, developed by DARPA, provides a contemporary example of a net-centric system and therefore an opportunity to study the translation of theory into practice from a command post perspective. As in other military contexts in Iraq, evolution is occurring in the command post. Decision makers are learning to adapt as they deal with a complex environment that is frequently unpredictable and ambiguous. As in other complex socio-technological environments, these decision makers are also learning and adapting their use of the technology they utilize to do their work. Because actions in CPOF are automatically saved in a repository, as part of a backup and recovery system, there is an opportunity to leverage that data as a record of these events since April 2004 to provide feedback that can help create an adaptive command environment. In such an environment support for adaptation can be provided by utilizing previous patterns of adaptation and by improving awareness of battlespace and command staff activities or conditions that should cause adaptation. In this research effort we have combined repository analysis, with cognitive task analysis and social network analysis to help determine the requirements for such a system. We have also used information visualization and interface design to produce a graphical user interface for a prototype solution called C2*insight*. Subject Matter Experts indicated this type of system is of high value because it provides contextualized feedback and decision support using patterns of behavior that were previously difficult to identify. They also provided scenarios for how the system could be used in realistic and significant situations.

INTRODUCTION

DARPA's Command Post of the Future

Recognizing that the commander's success depends on using information dominance to increase the speed and the precision of his decisions, the Defense Advanced Research Projects Agency (DARPA) began the Command Post of the Future (CPOF) program with the goal of shortening the commander's decision cycle to stay ahead of the adversary's ability to react. Since April 2004, CPOF has been deployed and heavily leveraged in Iraq. It was first used with the 1st Cavalry Division and then by the 3rd and 4th Infantry Divisions. It is used primarily at the Division Headquarters and the Brigade Headquarters to enhance situational awareness and operational/tactical planning and execution. It also provides the backbone for the distributed BattleStaff Update Briefs (BUBs) and Commander's Update Briefs (CUBs), saving travel through dangerous areas to a central briefing location.

The original concept for CPOF was place-centric and focused on the individual with a single common operating picture. The current concept, however, assumes a distributed and collaborative command and has a team focus with support for shared communications and thoughts. CPOF supports collaboration between superiors, subordinates, and peers. Working in composable, usually map-based workspaces, CPOF users create and manipulate icons, text and graphical annotations, tables and charts, creating an operational picture relevant to their decision making needs and those they collaborate with. By sharing their workspaces and establishing a VOIP communications channel with one or more other CPOF users, collaboration can take place with the benefit of *common ground* (Clark, 1986) established through a common visual referent and speech synchronized with annotating and deictic gesturing. This form of gesturing is natural when problem solving and communicating about graphical imagery (Tang, 1991) and software that supports it has been shown to improve the efficiency of collaborative problem solving compared to software that only supports text and pen-based annotation on maps. (Chapman and Smith, 2003). CPOF further includes a novel "flashlight" tool as an alternative to a regular pen-marker that "fades away" on the screen to efficiently accommodate temporary marking and graceful transitions when directing attention.

CPOF also supports virtual "looking over the shoulder", so that users can unobtrusively observe the current status and activity of each other. It is known that those who share a physically common workspace and have an understanding of the goals, tasks, and knowledge of their teammates can often coordinate their work without discourse (e.g. Heath and Luff, 1992), so it is perhaps not surprising that CPOF users take advantage of this capability. In this context, for instance, a Commander can view the Intel Officer's desktop to determine the current status of that officer's Intel operations, or a Brigade Battle Captain can view a Division Battle Captain's desktop for a more global perspective of the battlespace. Entire windows can be shared or only subcomponents, such as a collection of icons put in an "effort box".

Ryan Paterson, the CPOF Program Manager for DARPA, also noted the level of innovation in CPOF as a deployed C2 system in his presentation at DARPATech (Paterson, 2005):

"When DARPA contractors teamed with Soldiers from the 1st Cavalry Division to take this experimental technology to war, it was a huge leap of faith on the part of a visionary leader and a dedicated group of his Soldiers." (p16). He then quotes Major General Peter Chiarelli, as the leader who took that leap on the basis of the potential he saw and his confidence it would be achieved:

I think it is going to have an impact, not only on tactics, techniques, and procedures we use to command and control. I think it is going to have an impact on the size of our staffs, and what our staffs do. The wargaming process is so critical to the Military Decision Making Process, it [CPOF] is going to change everything we do and how we fight. I, in 32 years in the Army, have never seen a single system that will have a greater impact on our Army and our entire Joint Force than CPOF.

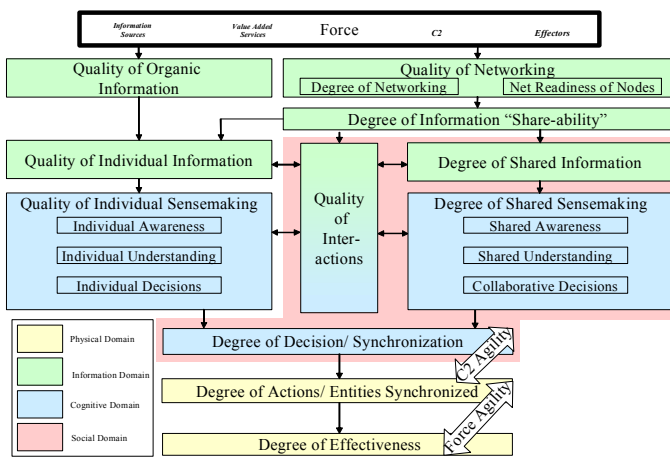**Network Centric Operations & Adaptive Command**

Figure 1. Network Centric Warefare Conceptual Framework (Alberts, 2003)

Much has been written about Network Centric Operations and Warfare, and what will be required to fully transform our military to operate successfully in such an environment. CPOF provides a case study involving real people in real work operations existing in a net-centric environment. Figure 1 is a conceptual framework for Network Centric Warfare and the characteristics of CPOF can be mapped to the concepts in this framework from a physical, information, cognitive, and social perspective. However, it is also important to note that this net-centric system exists in a very dynamic environment that frequently involves specific circumstances our forces have not trained for and thus requires them to be particularly agile and adaptive. Current literature on net-centric operations emphasizes this requirement. For instance, Joint Vision 2020 emphasizes the importance of developing leaders who can

adapt and be innovative. This document also recognizes another important aspect of net-centricity as it notes that these capabilities will be required of relatively junior officers:

"...*as new information technologies, systems, and procedures make the same detailed information available at all levels of the chain of command, leaders must understand the implications for decision-making processes, the training of decision makers at all levels, and organizational patterns and procedures. The potential for overcentralization of control and the capacity for relatively junior leaders to make decisions with strategic impact are of particular importance*". (pg. 33)

This type of decision-making at the junior leader level is necessary in Iraq, because of the distribution of operations, the pace of operations and the fact the conditions are frequently outside the scope of what is prescribed in doctrine or training, or covered by detailed orders. These leaders instead use their own assessment and initiative in executing the commander's intent until they are in a position to receive feedback on their performance. Leonard Wong (2004) examined the Operation IRAQI Freedom environment by interviewing 50 junior combat arms officers and concludes that the complexity, unpredictability, and ambiguity of postwar Iraq is producing a cohort of innovative, confident, and adaptable junior officers.

The CPOF users are also adapting in Operation IRAQI Freedom. Their environments frequently present new and challenging conditions where they need to interpret, act and learn. In addition, they are learning to optimize the utility of CPOF itself to help them do their work. Major General Chiarelli predicted that there would be a significant impact on command post staff activities, as well as tactics, techniques, and procedures, and this begs the question what that impact is. A feature of CPOF that can help the process of identifying and utilizing what has happened so far in Iraq is the automatic capturing and saving of user actions to a repository. For instance, icons representing annotated infrastructure, red force events, blue force tasking and units, and pen marks representing boundaries and planned movements, are all captured and importantly "pedigreed" so that who created or updated what is saved. At DARPATech Paterson summarized his focus with the CPOF Program in a set of questions he said must now be answered: How can we harness this newfound power to capture live combat? How can we use it to pass along the combat experiences of today to the combat leaders of tomorrow? Can we really teach people to master ambiguity, change, and complexity? And can we test, measure, and enhance an individual's intuitive knowledge? The enhancement referred to in this last question would be part of the Adaptive Command Environment that Paterson then calls for to help support the adaptation that CPOF users are currently engaged in.

In a preliminary study (Dunkelberger et al., 2005) dubbed the Multi-echelon Adaptive Command Environment (MACE) during the summer of 2004 data repositories from Iraq were analyzed. This work demonstrated the feasibility of extracting CPOF data and produced a set of initial analysis methods and

patterns in the data that were hypothesized to be useful. These included capabilities to: match activity level patterns across workspace pairs; determine periodicity within a single workspace; determine sharing patterns of CPOF objects over time; determine patterns of CPOF component usage for particular workspaces; and determine the life-cycle of CPOF components for particular workspaces. It was concluded that such analysis could be leveraged to guide component and service development in areas such as learning and reasoning (accelerating the C2 processes for which CPOF is intended), knowledge management (increasing the efficiency of the data, information, and knowledge resident therein) and team formation (accelerating the discovery and matching of problem to problem solver).

In the spring of 2005 a second effort was launched to conduct further analysis on repository data from Iraq and to identify how that type of data, and the particular datasets analyzed, could be used to create support tools for a more Adaptive Command Environment. The remainder of this paper describes the approach that one team took and the results produced that are suitable for an unclassified publication. That team was formed by CHI Systems, Inc. and Carnegie Mellon University and involved a multidisciplinary approach combining expertise in Human Factors, Cognitive Science, Computer Science, and Systems Engineering.

A Cognitive Systems Perspective

Researchers of complex systems where there is significant human interaction sometimes reference Neisser's (1976) Perceptual Cycle as a simple model of cognition that reminds us that such interaction occurs within a cycle. Human visual perception is followed by reasoning on that which is perceived in the context of the individual's cognitive system, followed by an action that changes that which is the focus of the person's perceptual attention. This basic model is true for human interaction with our environment in general, as well as technological systems that exist in a particular environment, such as occurs when a user interacts with a dynamic computer-based representation of the battlespace.
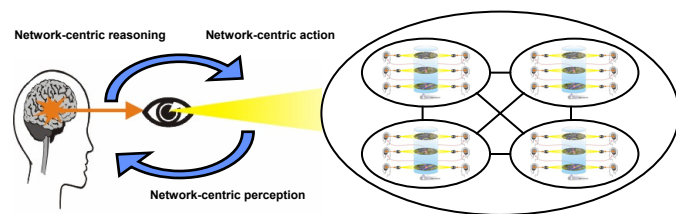

Figure 2. A net-centric perceptual cycle

However, as shown in Figure 2, CPOF users operating in their net-centric environment actually need to be able to efficiently perceive that which is significant in the dynamic network of interrelated entities that include collaborating decision makers each with their own view of the network. These users also need to be able to form efficient mental models (Gentner and Stevens, 1983) of the network, so that they appreciate relationships that are significant to their goals and tasks, and finally they need the ability to be able to act efficiently in their net-centric environment in order to translate a planned action in their mental network model into a corresponding execution in their environment.

Net-centric perception can be assisted through interfaces that provide the information needed for a particular user's or team's situation detection or decision making. Representation aiding (Zhang and Norman, 1994) can then support further efficiency by taking the 'what' needs to be displayed and focusing on the 'how' it should be displayed given the expected processing of that information.

Net-centric action that can benefit from assistance in this context will include switching focus to different information in the network, retrieving information, and requesting or providing information to others synchronously (e.g. via VOIP) or asynchronously (e.g. by adding information to an icon).

CPOF users engage in collaborative sensemaking and coordinated action, but the processes involved are often in the minds of the users rather than in documented tactics, techniques and procedures. This is frequently tacit knowledge (Gasson, 2005) that is undocumented, but potentially could be discovered by automated learning systems that look for evidence of those processes in the CPOF repository. Utilization of that learning could even be incorporated in CPOF with various forms of semi-autonomous software to create effective virtual "team players" as long as we learn from the experience of other systems that have taken this approach and make their activities observable and directable (Christoffersen and Woods, 2002). Another approach, not incompatible, is to continue incorporating the type of benefits CPOF has as a system with sophisticated direct manipulation (Zielgler and Fahnrick, 1988) and human-human collaboration capabilities, but support more discovery of this tacit knowledge in the CPOF repository by users themselves, complemented by proven information visualization (Tufte, 1990; Ware, 2000) and data analysis techniques.

Cook and Brown (1999) identify four types of knowledge that bridge the epistemologies of distributed organizations: know-how, know-what, know-why, and know-who (or who-knows-what). Johnson et al. (2002) argue that the codification process tends to reduce knowledge to a distinction between know-what and know-how, but that know-why and know-who are equally important. In developing an Adaptive Command Environment for CPOF, that utilizes patterns of behavior and other data in the CPOF repository, this is particularly relevant. The context for stored actions that were taken can help put those actions in perspective, thus helping determine the know-why. The know-who is also particularly important, as it helps determine trust in the data and sometimes who to contact when seeking to utilize that knowledge fully.

In addition, there is also a social aspect to the set of CPOF users that is important when designing support for enhanced adaptation. It can be informative to have feedback such as who collaborates with whom, what are the roles within the various teams and teams of teams, and what tasks do team members

and teams become engaged in. Even though CPOF is clearly a sophisticated tool for enabling a commander to view others' workspaces, the system does not have rich overviews that show at a glance these types of social relationships.

METHOD

Our approach to creating an Adaptive Command Environment is human-centered, but multidisciplinary as we have combined human factors methods for performing a cognitive task analysis and for designing a graphical user interface prototype, with social network analysis methods for the computational analysis of this social and organizational system. Because our analysis also involved extracting and aggregating real-world CPOF performance data and our solution is being designed to integrate with the current CPOF architecture, there is additionally a significant computer science component to this research and development effort.
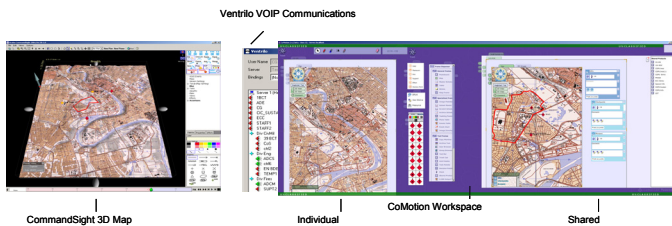
CPOF Repository Analysis

Figure 3. A typical allocation of screen-space to the CPOF applications – CommandSight, Ventrilo and CoMotion

CPOF is normally operated across three screens side-by-side. A typical layout is shown in Figure 3. Based on Oculus's CommandSight 3D mapping software and Maya Viz's client/server CoMotion software, CPOF encodes all information (within storage repositories or network communications) as Universal Forms, or Uforms. Uforms are data objects consisting of a universally unique identifier (UUID) and associated attributes and values. For example, a graphical object such as a circle might be represented by attribute value pairs for graphical type, coordinates, and radius. The representation of an entire workspace composition consists of many Uforms connected only through UUID references (one Uform's attribute value is the UUID of another Uform). This is an extremely flexible and efficient solution, but results in data which are highly fragmented and abstract. Although directly viewable from the workstation perspective, data are not readily viewable in any other form, such as might assist a commander in developing situation awareness. Due to the format of Uform data, pattern extraction is also a significant engineering challenge because the first step has to be to retrieve data and build a scheme for that data that facilitates identification of useful patterns.

Voice communications in CPOF are facilitated through the use of an additional application called Ventrilo (also

shown in Figure 3, positioned behind the CoMotion application as users normally do). This application supports VOIP communications, were the cell structure of the command post maps to separate "channels" ("Civ Mil", "Div Eng", and "Div Fires" in Figure 3) in Ventrilo. When an ad-hoc team is needed those users can further meet on a "Spare" channel. Unfortunately, Ventrilo interactions are not part of the backup and recovery system. We therefore developed a separate application to detect and log changes made to the Ventrilo application's hierarchical channels status display.

Social Network Analysis

A social network graph consists of actors and relationships between them. Actors (or "nodes") normally represent people, teams, or organizations. Relationships between actors are represented by links between the nodes (Borgatti and Foster, 1993; Borgatti, 1994; Hanneman, 2001). Relationships in a network that connects pairs of actors can be directed or undirected, thus supporting non-symmetric relationships such as "gives instructions to" and symmetric relationships such as "is physically located with". Relationships can also be dichotomous (present or absent, to represent, for instance, whether two people are collaborators or not) or valued (measured on a scale, to represent, for instance, the strength of collaboration or the probability information is passed between actors). In social systems, people influence each other, the ideas being exchanged, and the flow of information. Social Network Analysis (SNA) seeks to quantify these relationships. SNA allows for values to be attached to these relationships, thus presenting a means for mathematically evaluating the network.

When the focus of attention is on a single actor, the actor is called "ego" and a network consisting of this node, those connected to it, and the relationships among that set of nodes (including those to ego) is called an ego-network. One aspect of SNA is to study how individual actors are related to their ego-network or a larger network that contains the ego-network, but a network analyst will also view a network more holistically to determine characteristics such as the overall number of relationships between pairs of nodes that exist given how many could exist (i.e. the density of the network for that relationship).

Figure 4, for instance, shows information sharing in an organization (based on survey data) before and after interventions designed specifically to create more collaboration throughout the organization. The pre-intervention organizational network graph clearly shows certain situations exist at the network and node level of analysis. At the network level it can be seen that two relatively disjoint groups exist. At the node level it can be seen that Alam is a "boundary spanner" between the two groups and possibly also a "bottleneck" depending upon the actual information flowing and the capacity of the links. After using this network to seed discussion within the organization and exploration of the causes, interventions to restructure the workflow in this organization clearly produced a different

information sharing network. Cross et al. (2002), note that although managers may be able to diagram accurately the social links of the five or six people closest to them, their assumptions outside their immediate circle are usually off the mark. This is potentially a particular problem when digital communications in modern, network centric, distributed organizations makes it even easier for informal networks to form unseen. Thus, even structural models that don't themselves capture detailed reasoning, but reveal relationships that are otherwise hidden, can be valuable feedback.
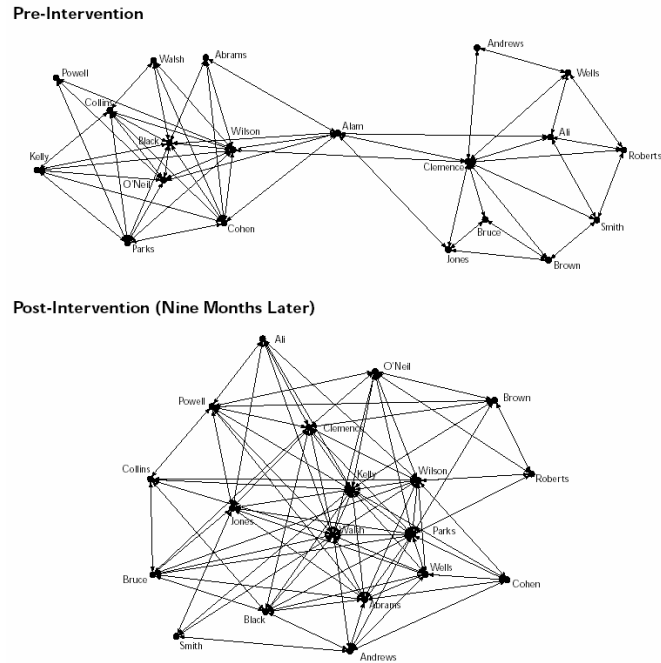

Figure 4. Information Sharing within an Expert Consulting Group (Cross, Borgatti, and Parker, 2002)

Carley (1998) has developed the concept of dynamic network analysis (DNA) as an extension to social network analysis. DNA considers the factors that lead to temporal change in network structure and performance. DNA also identifies entities and relationships, where an entity is not constrained to be only a person. This taxonomy is an extension of the nodes and edges that are the building blocks of SNA to include entities such as knowledge, resources, and tasks. Now relationships are the available edges between all types of entities and can include who communicated with whom, who knows what, what knowledge is related to what tasks, what organizations have what resources, etc.

Cognitive Task Analysis

To conduct a cognitive task analysis we observed and interviewed deployed CPOF users and those using the system in a battlelab experiment. We also worked with several retired Generals who had been involved in the design of CPOF. As we developed our understanding of how the system is used, we identified feedback that could realistically be produced,

extracted data from archived CPOF usage, and applied network analysis algorithms (using a CMU developed tool called ORA) on the data were applicable. We then presented these results to our SMEs to determine what feedback they felt was most valuable and how such feedback might influence tactics, techniques, and procedures.

	Workstation ID/ Role	Geosticky icon/ Location/ Infrastructure	Unit icon	Event icon	Task icon/ Mission	Time/ Episode/ Calendar Events
Workstation ID Role	**Communication/ Collaboration Network:** Who collaborates with whom? (e.g. via voice or shared resources) Who are the producers and consumers of information? (e.g. by creating/copying/ cloning/ event or task icons, workspaces, or flash-lighting) What are the teams? Who serves in key actor roles? (e.g. leader, boundary spanner, *guru*)	**Regional/ Infrastructure Management/ Knowledge Network:** Who has knowledge about events or operations connected to particular regions or in proximity of particular infrastructure?	**Unit Management/ Knowledge Network:** Who has knowledge about blue, red, or neutral units?	**Event Management/ Knowledge Network:** Who has knowledge about particular Events or Event types?	**Task Management/ Knowledge Network:** Who has knowledge about particular Tasks or Task types?	**Personnel Activity Network:** When are people particularly active or inactive?
Geosticky icon/Location/Infrastructure		**Inter-Infrastructure Network:** Areas of high density (e.g. mosques, oil-wells etc.), hierarchical relationships (e.g. headquarters controlling regional offices)	**Infrastructure-Unit Network:** What infrastructure is unprotected? Where are we patrolling? What are the most frequent intersection points for known routes? What locations are popular with the bad guys?	**Infrastructure-Event Network:** Where do particular events tend to occur? (e.g. near particular building types, geographic features, or in particular regions independent of local features)	**Infrastructure-Task Network:** Where are our efforts and maneuvers concentrated?	**Infrastructure Activity Network:** What infrastructure has been added or destroyed? When is there a lot of activity at these locations?
Unit icon			**Inter-Unit and Intra-Unit Network:** Who has engaged these enemy units? What is the hierarchy for the enemy units? What is ours?	**Unit-Event Network:** Which units have been involved in what Events?	**Unit-Task Network:** Which units have been involved in what Tasks?	**Unit Activity Network:** When have particular units been active?
Event icon				**Inter-Event Network:** What is the hierarchy of events? Which events tend to occur together?	**Event-Task Network:** Are events occurring close to our maneuvers or are they avoiding them?	**Event Activity Network:** When do particular events occur most frequently? Do they ramp up or spike?
Task icon/ Mission					**Inter-Task Network:** What is the task hierarchy? Which tasks occur together?	**Task Activity Network:** When do particular tasks occur most frequently?

Table 1. A matrix of entity-relationships and the questions such feedback can answer
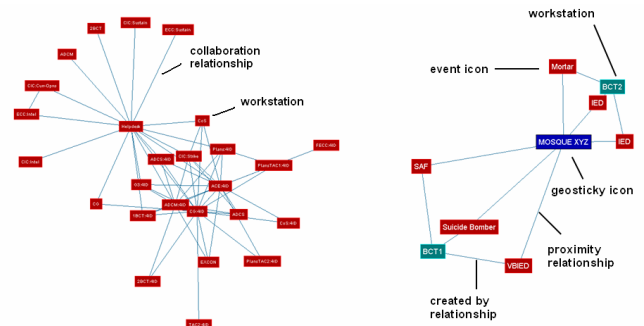

Figure 5. A workstation x workstation network and a workstation x event x geostructure network

The initial sets of entity-relationships we either extracted or determined it was feasible to extract are shown in Table 1. Figure 5 shows two network graphs that represent a subset of the relationships in Table 1. The first is a social network that

indicates who is collaborating with whom. In CPOF such collaboration could be from shared entities such as workspaces or battlespace objects, from voice communications, or from some combination of both. Social network analysis algorithms on such a network can reveal who are the key actors (e.g. a leader or a boundary spanner between groups) and what teams have formed. The second graph shows who has created what event icons and where those icons exist on a map relative to a particular instance of infrastructure (in this case a mosque). Thus, it indicates not only which events have occurred in a particular area, but who has knowledge about those events. Network graph algorithms can be applied to larger quantities of this type of data to determine general relationships such as which infrastructure tends to have events occur in its proximity and which users are the most knowledgeable with regard to these events.

When SMEs were shown Table 1 and asked to identify scenarios where such relationships could be utilized they produced scenarios that can be categorized into different operational contexts. The following are examples:

Briefings
- Pre-BUB and CUB automated reports for CG and others
  o Provides the CG with an independent assessment
  o Facilitates better use of time
- Presentations during briefings
  o What are the red force patterns?
  o What actions seem to reduce attacks on us?
- During briefings question answering
Intelligence Analysis
- Is there evidence to support a tip that a police chief in one area is corrupt?
Planning
- Deciding who to bring into a planning session based on their knowledge
Execution
- The Division battle captain tracking expected activities of the Brigade CPOF users
General
- Annotation of CPOF icons based on risk factors

Visualization Needs Analysis
Information visualization design principles, such as those described and demonstrated by Tufte (1990), can help improve efficiency in net-centric perception and processing. For instance, the concept of *micro/macro readings* is relevant here when we present a large network of nodes and want simultaneously to support both meaningful "big picture" macro views and detailed micro views presented in perspective of the macro views. The concept of *layering and separation* is also clearly relevant, where we, for instance, can use color to code different types of node and position the nodes to help the viewer identify network relationships between the nodes (e.g. a boundary spanner relationship). This technique visually stratifies various aspects of the data.

Tufte also states a general principle of information visualization that is followed in more sophisticated designs:
"Confusion and clutter are failures of design, not attributes of information. And so the point is to find design strategies that reveal detail and complexity – rather than to fault the data for an excess of complication." (pg 53).
In this context we are identifying relationships within and between network graphs, but we also recognize our users tend to be map-centric in their mental model of the battlespace and for many decision making situations this frame of reference can reveal relevant details in those geographic features. Early on in this research we therefore hypothesized that placing a network graph of entities in a third dimension above relevant entities on a geographic map, and linking them together, could be a powerful visualization.
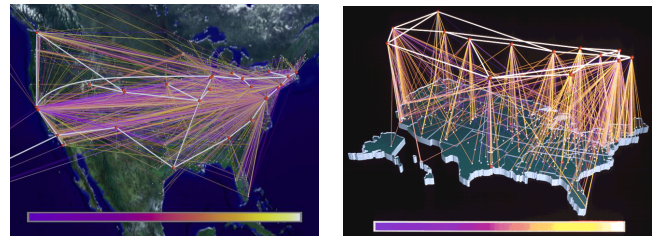

Figure 6. Visualizations of the NSFNET (Cox & Patterson, 1992)

Figure 6 demonstrates this is not an entirely original idea as the underlying visual technique was used by Cox and Patterson (1992) to overlay the NSFNET's backbone on a geographic map of the United States. In the left image, the backbone is overlaid in 2D space, with the traffic levels coded by coloring the links between location nodes. In the right image, the process is repeated, but the backbone is elevated into a vertical third dimension. However, we are not only looking to create performance improving visualizations of information. We are also seeking to support user interaction with those visualizations and to make transition from one visualization to the next as intuitive, efficient, and valuable as possible. This can be achieved through what interface designers refer to as an *overview*, *summary*, or *longshot* display (Chapman & Carlson, 2004; Woods & Watts, 1997). In such displays the user is able to see "the big picture" or overall status of a complex system without every detail shown at one time. Information is put in context in a meaningful manner given the informational needs of the observer, and in a form that helps guide the user's attention to that which deserves a more immediate response. From such a display the user is able to pursue more detail in a natural manner from the overview and, where appropriate, to reorganize the information to efficiently provide alternate views that reveal further facts or relationships about the data shown. Overview displays include specific capabilities to support interactions with the display. Namely: (1) "Big picture" views; (2) Related views; (3) Zooming; (4) Filtering; and (5) Details-on-demand.

RESULTS

The entity-relationships shown in Table 1 and Figure 5 were considered valuable by the SMEs, but they frequently commented how they could be more valuable with additional context. For instance, they wanted to see changes in the metrics associated with relationships over time; they wanted to see temporal scales annotated with significant events such as religious holidays and elections; and they wanted to see relationships to specific locations on annotated geographic maps. This guidance combined with that for overview displays and information visualization in general led to the interface prototype shown in Figure 7, for a system we call C2*insight*. In this particular simple example it can be seen who has created what event types, and where they occur on the map. Further, those around a particular mosque have been selected, and highlighted, so that relevant relationships can quickly be seen, but kept in a broader context.
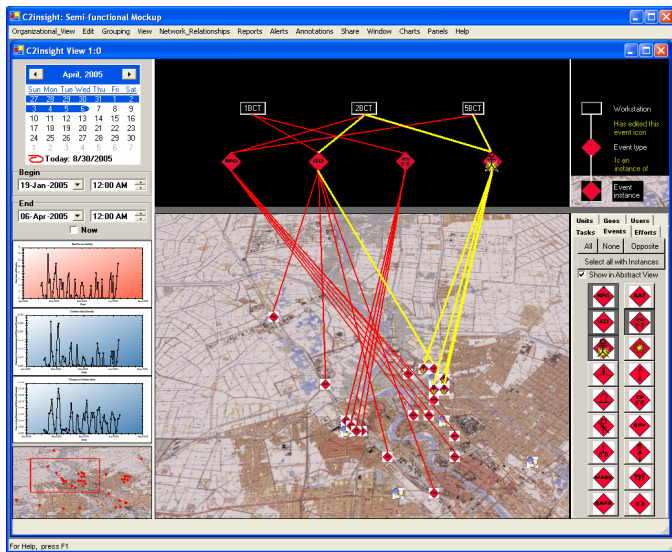

Figure 7. C2*insight*: Contextualized C2 Network Visualization & Analysis

"Big picture" views: C2*insight* supports these views from more than one perspective. The geographic information is presented as a coupled map-overview and map-detail-view pair. The geographic map-overview shows the broader perspective, indicates with a red rectangle what portion of that is shown in the detail-view, and provides a coupled navigation system. The timeline and other statistical charts can also provide an overview when their data range is broad. Further, the social network graphs themselves can provide an overview when the relationships shown are high-level, such as who is creating what type of event or task icon.

Related views: It is important to show the overview information with the related detail information to help put the detail in perspective. Other relationships are captured by showing statistical charts in parallel (e.g., number of events created over time in parallel with level of staff collaboration

over time) and a network graph could be complemented by a coupled table of entity-relationship details sortable by various attributes and metrics.

Zooming: One way to focus and obtain more information is to 'zoom', where more information is obtained about a subset of the data by changing the range of interest on a scalar metric. For instance, in C2*insight* the user can change the date/time range or grid coordinates range.

Filtering: Filters in C2*insight* include those for CPOF entities, such as, workstations, tasks, events, days of the week, and user-defined groupings (e.g. all geostickies that end with the word 'mosque').

Details-on-demand: In C2*insight* a user could obtain the same information about an entity as can be obtained when working with those icons in other CPoF applications, but new details such as the relevant network relationships and network measures could also be displayed. A network node that actually represents a class/type (e.g. type of event rather than instance of a particular event) could also be expanded on-demand to reveal the associated instances.

Direct manipulation is widely accepted as desirable for most graphical interfaces. It involves the user directly manipulating meaningful representations in an interface in intuitive and natural ways, by for instance pointing and "touching" an object to reference or select it respectively, or 'dragging' the object to move it. C2*insight* will support direct manipulation wherever possible, including the ability to select nodes in the geographic space and move them to the region above the map that does not normally position nodes according to their geographic location. The intention is also for nodes that are currently not shown on the map, but which have a geographic location property to be movable onto the geographic map. There will however be times when the user wishes to identify a set of objects that is not easily achieved with direct manipulation of the objects on the map or in the network, and in that case a standard query language, such as SQL, may be a valuable additional feature.

CONCLUSIONS

In C2*insight* we seek to:

- Utilize captured live combat data to improve feedback in the command post about staff and battlespace activities,

- Use social network analysis to help find significant patterns in the CPOF repository data,

- Integrate feedback with annotated CPOF components & user/role specific reports,

- Provide flexible support for user initiated pattern discovery / question answering,

- Provide contextual information to help users create searches & interpret results (e.g., geographic, temporal, significant events),

- Support configuration & adaptation, and

- Make the system more usable and useful by applying cognitive task analyses, and human factors display and direct manipulation interface design principles during design and development.

The overall primary goal is to reduce the time taken for the commander and staff to identify and communicate the types of information they currently seek, and to support the utilization of new types of useful information. For instance, in response to our interview questions, members of the 1st Cavalry Division (1CD) indicated that much of their time was spent preparing for the battle update briefs (BUBs) and commander's update briefs (CUBs) that are used to update the commander general (CG) on activities that have occurred and are planned. During these briefings the commander also requests further information and communicates his intent. We seek to make this process more efficient.

More generally, this research represents studying how to provide performance improving feedback to a distributed organization where collaborative work is influenced by particular technologies, but also by adaptive individuals and teams who seek to utilize the information available on the network to problem solve effectively. Social network analysis methods appear to provide valuable tailorable metrics and representations for the results, but additionally human factors methods appear to be very complementary by helping to create a feedback system that is both useful and usable.

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