Teams-of-Teams Performance Assessment through Multi-Channel Interaction Monitoring

Bruce Skarin, Dr. Shawn Weil, Dr. Andrew Duchon, Courtney Dean
Aptima, Inc.
Woburn, MA
sweil@aptima.com, bskarin@aptima.com, aduchon@aptima.com, cdean@aptima.com

Daniel Olguin Olguin, Taemie Kim
MIT Media Lab
Cambridge, MA
dolguin@mit.edu, taemie@media.mit.edu

Alan Jaeger
Naval Postgraduate School, Center for Asymmetric Warfare
Point Mugu, CA
ajaeger@nps.edu

ABSTRACT

In complex command organizations (e.g., military command and control centers, homeland security incident response groups), close coordination of ad hoc and quasi ad hoc teams of teams is required for effective outcomes. Understanding the dynamics of the individuals, teams, and organizations responding to complex and urgent tasks can provide leaders with key insights into the performance of those groups, and can lead to improvements in training and education. Information about these dynamics is embedded in communications occurring simultaneously through several mediums (e.g., face-to-face, telephone, radio, e-mail) used throughout an exercise or event. To leverage this information, a set of non-invasive social and informational monitoring technologies was deployed to capture the behavior and interactions of participants in Costal Trident 2009, a live multi-agency response exercise run by the U.S. Navy's Center for Asymmetric Warfare. Costal Trident consisted of two half-day exercises at the Port of Hueneme, CA, which is a shared civilian and military port. The scenario required collaboration across city, county, civilian, and federal agencies. The exercises included both (1) a simulation of a multi-agency distributed Emergency Operations Center (EOC) and (2) an in-the-field simulation of an Incident Response organization coordinating the activities required for a multi-faceted homeland security incident. Interaction data was collected from e-mail, telephone use, and face-to-face communication (using the MIT Sociometric Badge). With the data collected we were able to identify multiple performance and diagnostic indicators of individual and agency interactions. The results of the analysis and the implications for training and education are presented. Application of this approach introduces a broad range of possibilities for assessing performance in situ and in facilitating the response of diverse organizations to real world challenges.

ABOUT THE AUTHORS

Bruce Skarin is a Simulation Scientist at Aptima, Inc. and his interests include modeling complex dynamic systems with a focus on socio-cultural behavior, networks, knowledge management, and organizational dynamics. At Aptima, Mr. Skarin works on models of cultural influence and social identity to forecast changes in local populations for the purpose of assisting strategic military planning. He is also working on the development of systems for automatically assigning metadata and for improving group collaboration. Mr. Skarin received a B.S. in System Dynamics from Worcester Polytechnic Institute and is a member of the System Dynamics Society.

Dr. Shawn Weil is a Cognitive Psychologist and Director of Aptima, Inc.'s Modeling & Simulation Division. Dr. Weil's interests are in data overload, team coordination, and human language processing. At Aptima, Dr. Weil works on projects focused on team coordination, team adaptability, and the control of semi-autonomous agents. Prior to joining Aptima, Dr. Weil explored the perceptual consequences of nonnormative speech (e.g., foreign accents, noisy speech) in a project supported jointly by the Air Force Research Laboratories (WPAFB) and Sytronics, Inc. At the Ohio State University, he was affiliated with both the Language Perception Laboratory and the Cognitive Systems Engineering Laboratory (C/S/E/L). Dr. Weil received a M.A. and a Ph.D. in Experimental Psychology from The Ohio State University, and a B.A. in Psychology/Music from Binghamton University. He is a member of the Human Factors and Ergonomics Society, the American Psychological Association, and the Acoustical Society of America.

Dr. Andrew Duchon is a Cognitive Scientist at Aptima, Inc. with expertise in the areas of visual perception, statistical modeling, and computational linguistics (NLP). Dr. Duchon’s research involves the application of higher-order statistical models to problems in cognitive and language domains. At Aptima, Dr. Duchon is working on a number of projects related to automatic communications comprehension, text classification, and cognitive computing. Dr. Duchon holds a Ph.D. in Cognitive Science from Brown University, and a B.A. in Psychology and the Integrated Science Program from Northwestern University. He is a member of the Association for Computational Linguistics.

Courtney Dean is a research analyst at Aptima, Inc. Mr. Dean has extensive experience in survey development, job analysis, and test construction and validation, with a focus on social networking and rating convergence in assessment centers. Prior to joining Aptima, he worked at The Personnel Board of Jefferson County in Birmingham, Alabama, where he specialized in the development, administration, scoring and validation of multiple-component selection tools for local police and fire departments. Mr. Dean holds a M.S. in Applied Psychology from the University of West Florida and a B.S. in Psychology from Fort Hays State University and is a member of the Society for Industrial and Organizational Psychology.

Daniel Olguin Olguin received a B.S. degree in Electronics and Communications Engineering and an M.S. degree in Electronic Systems Engineering, both from Tecnologico de Monterrey Campus, Monterrey (Mexico) in 2003 and 2005 respectively, and a Master in Media Arts and Sciences from MIT in 2007. He is currently a PhD student at the MIT Media Laboratory. His research interests include wearable computing, context-aware computing, machine learning, pattern recognition, and organizational engineering.

Taemie Kim received a B.S. degree in Electrical Engineering and Computer Science from KAIST (Korea) and an M.S. degree in Electrical Engineering from Stanford University in 2003 and 2006 respectively. She is currently a PhD student at the MIT Media Laboratory. Her research interests include human-computer interaction, human behavior modeling and mobile feedback systems.

Alan Jaeger is the acting Director of the Naval Postgraduate School, Center for Asymmetric Warfare (CAW). The CAW is a research center focused on multi-jurisdictional, multi-agency response to asymmetric threats (terrorism and natural disasters) with specific focus on civil/military interface between federal, state, local and private stakeholders. Mr. Jaeger received a B.S. degree in Mechanical Engineering from the University of California at Santa Barbara (UCSB) and an MBA in Organizational Dynamics from California Lutheran University.

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Daniel Olguin Olguin, Taemie Kim
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Cambridge, MA
dolguin@mit.edu, taemie@media.mit.edu

Alan Jaeger
Naval Postgraduate School, Center for Asymmetric Warfare
Point Mugu, CA
ajaeger@nps.edu

INTRODUCTION

The effectiveness of a response to events ranging from small local incidents to large natural disasters often depends heavily on the successful coordination of multiple organizations and agencies. This coordination can be particularly challenging given the complexity of individual organizations and a growing number of communication channels. Understanding the dynamics of these communications and interactions can provide vital insights into the performance of a multi-agency organization's response to an event. This paper explores the use tools for monitoring multiple channels of interaction and communication for providing unobtrusive assessments of an evolving situation.

Multi-Channel Interaction Monitoring

Everyday organizations operate using multiple forms of communication including both formal (e.g., email, phone, text chat, file sharing) and social channels (e.g., one-on-one conversations, group meetings), both of which offer important insights into an organization's dynamics. Formal channels are more easily traced and have already been used to understand an organization's behavior and even make legal arguments such as in the case against Enron (McClain & Elkind, 2003). Yet, important communications are usually face-to-face (Kirkman, et al., 2004). Some previous research also anticipates the incompleteness of data based on e-mail communication and surveys (Grippa, et al., 2006). These findings highlight the need for more comprehensive monitoring approaches that capture both the formal and social dynamics of an organization.

In recent years, the social network analysis has become one of the dominant paradigms in the organization sciences (Borgatti & Foster, 2003). Social network analysis allows researchers and analysts to quantitatively study the social structure of organizations by conceiving of individuals (typically) as nodes in a network, and the relationships among individuals as arcs or connections among those nodes. These networks can be represented as matrices and mathematically manipulated to uncover patterns of activity indicative of different organizational states.

One clear application of social network analysis is the study of the workplace. Workplaces are seldom designed for solitary tasking. Regardless of domain or type of work, individuals interact with each other, collaborate with regard to desired outcomes, coordinate actions towards desired goals. These interactions are not stochastic; they are meaningfully related to the work that needs to be completed. Social network analysis can be used to examine these interactions. However, in work environments, multiple "social" networks can be generated (Table 1) *from formal and informal interaction data*.

The resultant networks uncover different types of information about the organization. For instance, a social network can be constructed based on who sends e-mail to whom; the sender and receiver are both nodes in the network, while the act of sending the message constitutes an arc between those nodes. In that same organization, a social network can be constructed based on the formal organizational structure; the nodes are the employees in an organization, while the arcs are based on the organizational hierarchy. These two social networks may contain the same or overlapping nodes or actors, but the patterns of arcs/connections will likely be different because individuals typically communicate with more individuals than simply their direct supervisors and subordinates. Table 1 describes some on the information that may be gleaned from networks constructed based on different sources of data.

Our research is driven by a fundamental insight: by combining and comparing networks, more information may emerge compared to examining networks in isolation. Consider the three networks illustrated in Figure 1. In each network, the nodes represent individuals in a company and connections captured through each measure reflect different types of interactions. The first, on the left represents an e-mail network. The arcs between nodes indicate that one or more e-mail messages were sent with either nodes as sender or recipient. The second network, in the middle, indicates physical proximity as captured by the sociometric badges. Note the three groupings of individuals with limited overlap, perhaps reflecting three separate office locations. There is one individual who is connected to no others; this individual may work from a home office. Finally, the network on the right represents telephone communications. The thickness of the line indicates the number of individual calls (or the aggregate number of minutes); thicker lines indicate a larger relationship.

Table 1. Network data sources in an organization

Data Source	Nodes	Possible Arcs	Description
E-mail, Instant Messaging, Short Message Service	Sender/Recipient	Sent messages	Direct point-to-point communication is probably the most common data source for social networks. It reflects explicit connections among individuals in an organization
Chat room membership	Chat room members	Common membership to a room	In chat communication, individuals belong to one of several rooms. Membership in these rooms can indicate interest in related subjects or work products.
Formal Organizational Structure	Organization members	Direct superior or subordinate relationship	The official "org chart" in an organization represents formal relationships among employees.
Physical Proximity	Co-located individuals	Physical proximity	Both formal and informal interaction among collaborators is often done in face-to-face situations. Sociometric badge technology (Waber, et al., 2007) can capture this interaction.
Telephone (Land, VoIP, Mobile)	Individuals or agencies with a telephone line	Telephone calls between lines	Direct point-to-point communication.
Radio	Individuals & agencies with radio access	Sender to passive listeners	Like chat room membership, coordinating organizations could be monitoring traffic on several channels. Nodes for message creation and "subscription" can be captured.

When the three networks are superimposed (Figure 2), these differences become more apparent. Some node pairs have multiple connections, while some have none. Looking at the differences between networks can lead to suggestions for organizational change, such as recommending that two individuals communicate, or that two individuals who do communicate use a different medium of communications. For example, the bottom-right most node in each network shares few connections via e-mail and telephone and no connections via physical proximity. One might conclude that this individual is too isolated, or that he is not taking advantage communications tools. Or, if you have scenario information to provide more context, that his volume of communications is misaligned with goals. Other places within the network that might benefit from new connections are circled in Figure 2.

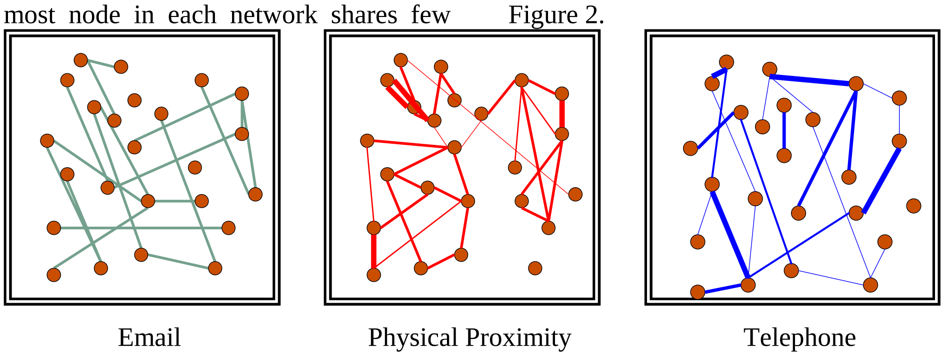

Figure 1: Three networks created within the same organization (hypothetical)

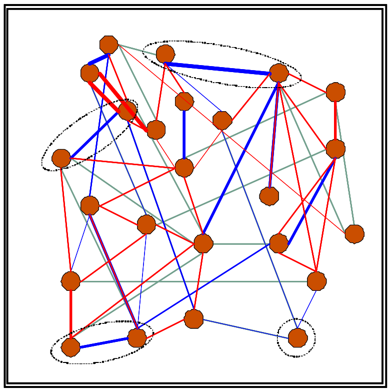

Figure 2: Aggregate network

Monitoring Formal Communication Channels

To monitor communications over formal channels and create these network representations, we developed a system the employs a desktop agent and server to collect information from a range of digital mediums. The desktop agent is used to collect local information such as user specified files, emails, and web history. The server component processes all of the desktop data and includes components for importing phone logs and other enterprise-level data.

Monitoring Social Communication Channels

Social communications are monitored using the MIT Media Lab's *sociometric* badge (Olguin, et al., 2009). The sociometric badge is a wearable sensor (see Figure 3) that MIT has already used in several real-world organizations to automatically measure individual and collective patterns of behavior, predict human behavior from unconscious social signals, identify social affinity among individuals working in the same team, and enhances social interactions by providing feedback to the users. The sociometric badge works by capturing proximity, face-to-face, voice, and motion data.

Figure 3: Participant wearing sociometric badge

The proximity and face-to-face interactions are collected by recording radio and infrared (IR) signals emitted and captured by each badge. The voice data consists of speech features that describe the duration, frequency, and pitch of speech, thus avoiding the privacy issues that are raised when content is recorded. Motion data is captured via an 3-axis accelerometer. Each badge logs this data on pre-determined time intervals ranging from one second to several minutes.

COSTAL TRIDENT 2009 EXERCISE

To explore how multi-channel interaction monitoring might be used in training and real-world responses to an event, we deployed the system at the Costal Trident 2009 Exercise, which was run by the Naval Postgraduate School's Center for Asymmetric Warfare (CAW). As part of its mission, CAW supports large scale exercises in a fully instrumented command and control environment to test multi-agency response to asymmetric threats such as terrorism. The Coastal Trident Exercise series was a three year program that began in 2007. The 2008 exercise focused on the Harbor District's ability to activate, staff, and manage the Oxnard Harbor District's (OHD) Emergency Operations Center (EOC) in response to a complex and demanding exercise scenario. In addition, the Facility Security Officers were tasked to exercise their personnel accountability and evacuation plans, as directed by the EOC. Also included was an Incident Command System/National Incident Management System and EOC Basic Function courses. This exercise and training fulfilled the requirement of the Maritime Transportation Security Act of 2002. The series has culminated in 2009 to a full two day exercise, which includes a one day table top exercise (TTX) and a one day full scale exercise.

The day one TTX objectives were designed to examine policy level issues regarding emergency response and security at the Port of Hueneme as it applies to Oxnard Harbor District, Naval Base Ventura County, Ventura County, and the local response communities. The exercise was also intended to help identify agency critical information requirements for local maritime and port based emergencies, validate the Harbor District's and individual terminal operator's security plan, and identify future training needs for the Oxnard Harbor District, its Facility Security Officers, and partner agencies. The day two objectives sought to examine policies and processes surrounding the establishment of a unified command structure in response to an evolving shipboard life-safety and security incident. This included conducting an onboard ship victim rescue and evidence recovery mission and a joint firefighting, HazMat, and law enforcement operation involving local fire, county fire, federal fire, police, and sheriff agencies.

These exercise objectives provide an ideal scenario for monitoring the intense inter-agency collaborations required using our multi-channel approach.

Exercise Setup

Day one of the exercise was conducted at the OHD EOC using a closed network of 17 laptop computers and 18 VOIP Phones. During the tabletop exercise, 76 participants from 32 agencies simulated and discussed responding to a shipboard fire scenario aboard a vessel that requested safe harbor at the port. Each laptop had an installation of the desktop agent for collecting emails. The VOIP log was processed after the exercise using the server component. A total of 28 badges were worn by the participants using the phones along with several observers. The exercise ran for a period of one hour, generating 93 completed calls, 130 emails, and over 50,000 interaction logs via the badges.

Day two of the exercise was held waterside at the Port of Hueneme. During the exercise over 130 personnel from 40 agencies responded to a simulated shipboard fire aboard a ship that had entered the Port against the direction of the U.S. Coast Guard. The scenario involved multiple plotlines that involved a wide variety of response specialties, including shipboard firefighting, search and rescue, medical treatment and triage, hazardous materials (HAZMAT) operations and decontamination, security and law enforcement, dive operations, vessel search and evidence collection, and explosives disposal. The responding agencies also established a multi-agency Incident Command Post (ICP) that included OHD, local law enforcement, military security, and local and military firefighting forces as part of a Unified Command. A total of 26 badges were worn by observers and leaders of key agencies. The exercise ran for a period of four hours generating over 7,000 badge-based interaction logs.

Preliminary Findings

The analysis of the Costal Trident data is still ongoing, yet the preliminary findings already provide promising evidences of issues and areas for improvement identified in the CAW After Action Review (AAR).

Day One TTX

One of issues identified in the AAR of the TTX was that response agencies had a difficult time getting access to critical information quickly enough to respond proactively to the exercise events. As a result, each agency had a different perception of the developing situation, leading to an insufficient common operating picture (COP). In a related finding it was noted that accurate and complete information needed to move more quickly between agencies

In examining the information flows from the exercise this finding is supported by the data collected. As shown in Figure 4, after twenty-minutes into the exercise, only five of the fourteen responding agencies had any connection to the distressed vessel Trinidad. By the end of the exercise there were still agencies that were unaware that the ship came into port.

Another issue identified in the AAR was that response agencies experienced difficulty in determining rapidly who was in charge and what they were in charge of. As shown in Figure 5, the Coast Guard is clearly in charge, serving as the primary link to the distressed vessel and for coordinating the response with the constituent agencies.

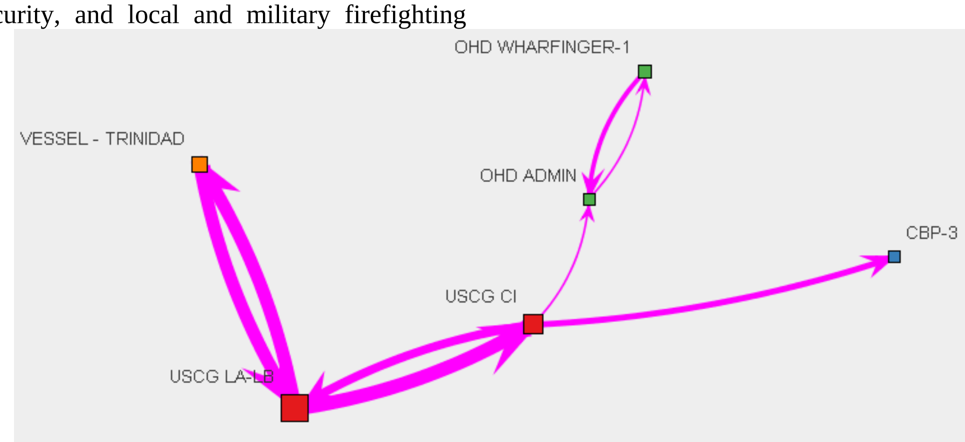

Figure 4: Communications twenty minutes into the TTX

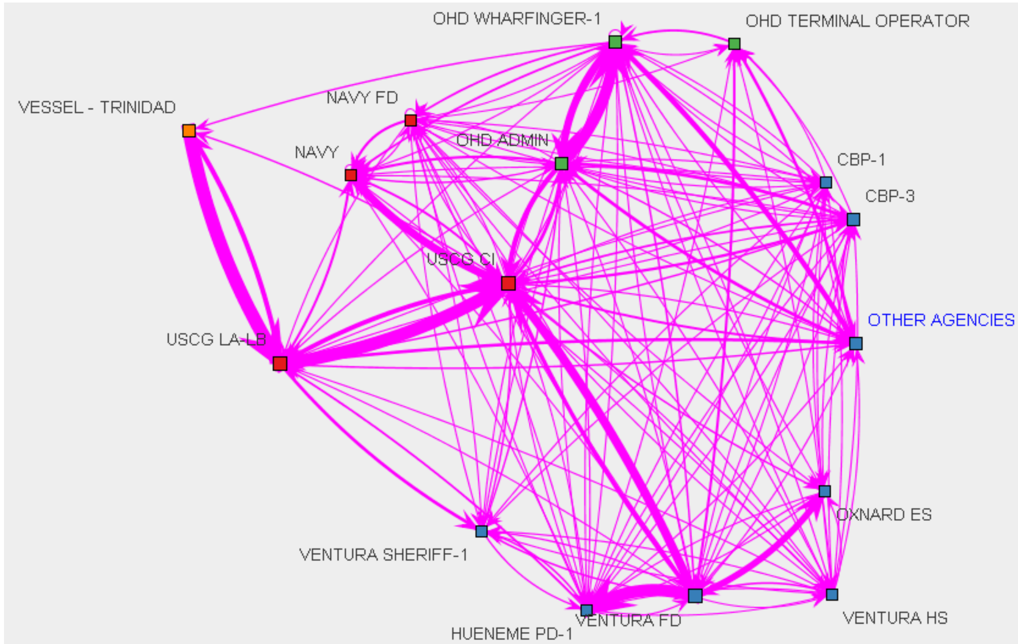

Figure 5: Cumulative Communications at the end of the TTX

Day Two Full Scale Exercise

During the full scale exercise two key badges unexpectedly stopped recording data shortly into the exercise. Despite the difficulties, the remaining badges were still able to capture evidence of some of the AAR findings. One of the main issues identified was the lack of a formal Unified Command. The Unified Command is intended to ensure coordination of operations among multiple agencies and disciplines for the effective dissemination of information. Agency Representatives had to be sought out by Incident Commanders. This issue detracted from the situational awareness of the collective response community and ultimately diminished the effectiveness and safety of the response. In examining the face-to-face interaction data over time there were several instances like the one shown in Figure 6, where agencies worked primarily independently. There were a few occasions when larger inter-agency groups formed, but at no point were the majority of the representatives present as was expected for periodic updates.

Another finding of the day two exercise noted that because a Unified Command was never formally established, agencies arriving to the scene did not know where to check in or with whom to coordinate their operations. The result was an initially disjointed and ineffectively coordinated response effort. While in this effort the users were not able to view information generated by data collected during the exercise, such monitoring could be use to help direct new arrivals.

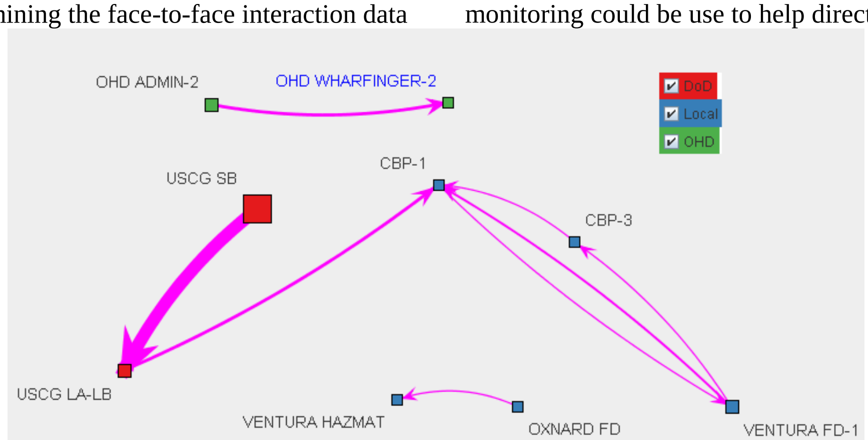

Figure 6: Organizational isolation

CONCLUSIONS

The initial findings of our multi-channel interaction monitoring have already shown promising potential for developing a more complete picture of the behavior and performance during complex multi-agency responses to events. This information can be used in a variety of applications including enhancing after action reviews, providing real-time feedback during training, and as an organizational aid in real world situations.

While the initial analyses only provide general feedback such as leadership identification, organizational disconnects, information overload, and lack of coordination, we expect to be able to identify more detailed behaviors. By incorporating some of the additional sensor data captured, such as voice features and accelerometer data, we expect to be able to provide other quantitative measures of the person-to-person interactions.

Future work could also include additional information channels that might help to provide context to information flows over time. In this example, participants did not generate significant textual information (i.e., they did not write e-mails, author reports, or use text chat). However, in situations in which there is a lot of textual information being generated, a "social knowledge" network can be created in which the nodes are individuals and the links are determined by having knowledge or interest in common. Using various topic extraction techniques such as Probabilistic Semantic Analysis (Hoffman, 2001), researchers have been able to determine common topics or themes in newsprint, intelligence reports, and even communications. If particular communications can be identified as being related to a particular individual, a "topic profile" can be created. Looking at the overlap among topic profiles associated with different nodes might provide some insight into shared interests.

While this network representation would be interesting in and of itself for evaluating shared concerns or conceptions of a dynamic situation, it could also be informative when compared with more traditional interaction-based network representations. For instance, if two nodes demonstrate a strong topical connection but a weak interaction connection (e.g., two people do not communicate but they have a lot of topics in common) it may be worthwhile for those to communicate more (e.g., similar interests may lead to creative partnerships). Conversely, a weak topic connection coupled with a strong interaction connection (e.g., two people who communicate often but have few topics in common) may indicate a poor use of resources. Clearly, such recommendations need to be contextually grounded to ensure that such suggestions be relevant.

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