

TOOLS FOR SUPPORTING TEAM COLLABORATION

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Collaboration plays an important role in team tasks. Teams are also functioning more often in a distributed fashion. If individuals are to work efficiently in a distributed fashion they will need collaborative tools and systems to exchange information and most importantly Situation Awareness (SA). Little guidance exists as to which tools are appropriate for collaborative tasks or situations. The present paper presents a taxonomy of collaboration and, based on this taxonomy, information is provided on which classes of collaborative tools and techniques are most useful for different types of tasks and situations.

INTRODUCTION

In many complex systems, tasks will often need to be accomplished through the joint efforts of several individuals. When individuals work together they are known as a team. Examples of teams of individuals working together to perform every day tasks include fire fighters, surgical teams, aircraft cockpit crews, command and control in military operations, and air traffic controllers. Performance depends upon the coordinated efforts of these individuals (Cannon-Bowers, Salas, & Converse, 1993). This is particularly difficult in dynamic environments where team members must continuously seek out new information, integrating it with existing information and sharing this information with relevant team members in a continual fashion. Additionally, it is becoming more common for such teams to work together in a distributed fashion. The main drivers for this change are faster response times, increased operational flexibility and a reduction in the number of workers (Sherwood, 1987).

If individuals are to work efficiently in a distributed fashion they will need collaborative tools and systems to exchange information and most importantly Situation Awareness (SA). While the term SA has received considerable attention, very little effort has been directed on how to improve SA for individuals and even fewer resources have been spent at how to improve SA for a teams of individuals. One way to support sharing of SA is through the use of collaborative tools and techniques. By providing the right collaborative tool at the right time team participants will be more likely create, maintain and share SA at a high level, which will be needed for distributed operations.

However, just providing team members with a method of collaboration will not ensure its success (Olesen & Myers, 1999). For example, if the goal of the collaboration tool is to increase SA, creating an effective shared SA device involves many issues. If every detail of the situation is present, finding that which is needed will be highly problematic for user. In addition a single type of collaboration will not be suited to an organization's needs. What works best for planning purposes may not be well suited to execution. Also, just because the device will be based on common information does not mean that it must be displayed in identical ways to every team member. The perspective and information presented to each team member needs to be tailored to its individual requirements, even though the devices may be created based

on a common database. Each team member will have different physical vantage points on the battle, different goal orientations and different semantics or terminology that must be supported. Yet, each team member will also need to be able to communicate with other team member.

The present paper will review current collaborative tools and evaluate their ability to support shared SA as well as other processes, such as planning and scheduling, within the context of distributed operations.

Collaborative Tools Categories

A number of different tools or devices can be considered for supporting collaboration across distributed teams. Categorically, these tools include: face-to-face, video conferencing, audio conferencing, telephone, networked radio, chat/instant messaging, white board, file transfer, program sharing, email, groupware, bulletin board and domain specific tools. These categories are not exhaustive but represent the more common tool categories. It should be noted that many different special purpose and commercial-off-the-shelf (COTS) products are available in each of these categories, and may encompass devices in multiple categories.

Face-to-face. Obviously a perfect collaboration environment occurs when individuals are collocated in the same room communicating face-to-face. Face-to-face collaboration also encourages social interactions between individuals or small groups as well as private conversations between people. Another important feature of the collaboration process is the use of social cues to determine behavior and assess the acceptability of decisions (Walker, Collings, & Richards-Smith, 1998).

Video Conferencing. Video conferencing involves using a computer network between two or more participants at different sites to transmit audio and video (images and text) data on a computer monitor in a conferencing format (Webopedia, 2002).

Audio Conferencing. An audio conference, also known as a teleconference, is a meeting among two or more participants who are connected over a network (Internet or Intranet), telephone or satellite link in real time and can communicate by voice and fax (Computeruser, 2002). One drawback to very large conferences is the inability to identify who is talking at any one time

Telephone. A telephone connection can be considered a simple form of an audio conference. However, audio information is only transmitted via a telephone or satellite link instead of a network. Like audio conferences, the inability to identify who is talking is a problem.

Networked Radios. Networked radios are frequently used in many operations to create a dedicated verbal communication system for multiple team members in distributed locations. Unlike telephones, these communications networks are generally “always on”, although different people may join and leave the network at different times.

Chat/Instant Messaging. Chat or instant messaging is real-time communication between two users via computer in which notes are recorded and messages are sent in real time (Webopedia, 2002).

White Board. White boards are typically a space on the display in which one or more participants write or draw, using a mouse, keyboard, or other input device. They are used for exchanging graphics and diagrams. An electronic whiteboard generally fall into one of three categories: standalone copy boards, where the content of the whiteboard can be scanned and printed out; peripheral boards, which transfer information in the form of digital files to an attached computer; and interactive boards which are like large touch screen monitors that can be synchronized to an attached computer (Searchnetworking, 2002b).

File Transfer. File transfer is the movement of one or more files from one location to another. On the Internet, the File Transfer Protocol (FTP) is a common way to transfer a single file or a relatively small number of files from one computer to another. For larger file transfers (a single large file or a large collection of files), file compression and aggregation into a single archive, such as a zip file, is commonly used (Searchnetworking, 2002c).

Program Sharing/Application Sharing. Program or application sharing enables conference participants to simultaneously run the same application. The application itself resides on only one of the machines connected to the conference and the individual who owns the application (it is on there computer) gives control of the program to the other participants (Webopedia, 2002).

Email. Email is short for electronic mail, which is the transmission of messages over computer networks. The messages can be notes entered from the keyboard or can be electronic files stored on a disk or computer (like file transfer). Most mainframes, minicomputers, and computer networks have an e-mail system (Webopedia, 2002)

Groupware. Groupware sometimes referred to as group support systems (GSS) are interactive computer-based environments which support team efforts towards joint tasks. They are designed to facilitate two or more users working on a common task in a shared environment by providing mechanisms for coordinating each user's actions with respect to the group and the system (Krasner, McInroy, & Walz, 1991).

Bulletin Board. A bulletin board system (BBS) is a computer that can be reached by computer modem dialing (and, in some cases, by Telnet) for the purpose of sharing or

exchanging messages or other files. Essentially, a bulletin board system is a host computer that is accessible by dial-up phone or, at some sites, via Telnet (whatis, 2002).

Domain Specific Tools. Domain specific tools work to transmit very specific information, tailored to the information transmission needs of particular individuals. For example, rather than using a phone or email to convey the location of a detected target in a military application, a domain specific tool would transmit that information from one person's displays to another's (often through a common database) any time a detection occurred.

COLLABORATIVE TOOL TAXONOMY

The evaluation of these tools was conducted through the development of taxonomy of collaboration. Both military and commercially available tools were identified. While the number of collaborative tools is immense, the types of collaboration techniques they employ are much smaller. This review does not strive to review all tools, but rather to identify and review specific collaborative tool types.

The collaboration matrix consists of several sections rating the degree to which the different categories of collaborative tools (described above) support different types of collaboration characteristics, tool characteristics, information types, and processes.

COLLABORATION CHARACTERISTICS

Important characteristics of the type of collaboration to be supported by the tools includes:

- **Time of collaboration** - individuals can collaborate either synchronously (real time with no lags) or asynchronously (different times)
- **Predictability of collaboration** - whether the collaboration will occur at a previously scheduled and predictable time, or at unscheduled unpredictable times
- **Place of collaboration** - collaboration can occur with individuals who are co-located or individuals who are distributed
- **Degree of interaction**

While collaboration tools are used for collaborating between individuals, the collaboration itself can occur in many different ways. Obviously time and place play a major role in many collaboration efforts. With distributed operations we can expect an increase need for tools that can support both distributed and asynchronous collaboration due location of team members and the possibility of team members being located in different time zones.

TOOL CHARACTERISTICS

There are also certain characteristics of tools that affect the types of collaborations that can take place:

- **Recordable/traceable** - Some tools provide raceability of the collaborations that can be drawn upon for creating an

audit trail or for bringing missing team members up-to-date.

- **Identifiable** – Tools also can vary in terms of the degree to which they allow for the individuals using them to be reliably identified by others involved in the collaboration.
- **Structured** – Tools vary in terms of the degree to which they allow for structured communications (of a very specific predetermined nature) or unstructured communications (allowing a wide variety of information types to be exchanged).

Recordable/traceable collaboration tools are necessary for good SA formation. Providing historical information allows the individuals to form a more complete picture of the situation and helps them in projecting future actions. On the other hand, tools that provide identifiable information help in the formation of team and shared SA as participants know who the information is coming from.

INFORMATION TYPES

Information types that may be involved in a collaboration include:

- **Verbal (Speech) information**
- **Textual information**
- **Spatial/graphical information** - such as maps or drawings
- **Emotional information** – including fatigue, workload, competence, and anxiety which are often important in team collaboration activities
- **Photographic information**
- **Video information**

A collaboration tool that support shared SA development will need to support all these information types as SA involves integrating information from multiple sources to form a clear picture of the current situation.

COLLABORATIVE PROCESSES

Finally, different collaborative tools are better suited to supporting different types of collaborative processes. Different types of team collaboration that are typically seen include:

- **Planning**
- **Scheduling**
- **Tracking information**
- **Brainstorming**
- **Document creation**
- **Data gathering**
- **Data distribution**
- **Shared SA**

While these processes are by no means exhaustive they represent the primary processes used by teams for collaboration. Finding a collaborative tool that can support all the processes used by a team is a challenge.

FILLING IN THE MATRIX

The taxonomy, presented in Tables 1, 2, 3 and 4 was developed as a method for determining which tool category best supports the needs of the individual collaborative environment for different classes of operations. For example, a collaboration between team members may be synchronous in time, unscheduled, with distributed individuals, who need a high degree of interaction for planning purposes. Their collaboration will be primarily verbal in nature and they do not need a record of their collaboration, but want to identify who is communicating to whom at any one time. Using the collaboration matrix specific tool types can be identified in terms of their ability to support this collaboration. In this example the matrix would tell us that chat/instant messaging supports almost all of the needed characteristics at a fairly high level followed by using a telephone. The net radio would do a fairly decent job if the individuals talking could easily be identified, while email and whiteboards would not easily support this collaboration.

The matrix is shaded signifying a tools ability to support specific collaboration characteristics, data types and collaboration processes. In the matrix light and dark colors do not always signify good and bad. Rather they signify opposing support by the tool. For example, under the column labeled “Place” the tools are rated on their ability to support collocated and distributed individuals. Tools that only support collocation are colored dark (e.g. face to face) and tools that support both collocated and distributed teams are light (e.g. white board). Variants of the colors are used to provide more fine grain distinctions.

COLLABORATION CHARACTERISTICS

As shown in the taxonomy (see Table 1), face-to-face, video conferencing, audio conferencing, program sharing, telephones and radio communications all require fairly synchronous collaboration, while white boards, file transfer, email, bulletin boards, group ware and domain specific tools allow for asynchronous collaborations. Face-to-face communications, video conferencing, audio conferencing and groupware have traditionally required a fair degree of pre-scheduling, although if cost is not an issue, “always on” technologies could provide unscheduled access to collaboration through these mechanisms. Other mediums provide the advantage of allowing unscheduled collaboration to occur fairly readily.

While face-to-face is singularly good at providing a high degree of interactivity in collaboration, other technologies fare less well on this criterion. Video conferencing, audio conferencing, telephone and radio provide fairly high interactivity, although not generally as much as face-to-face communications, in that subtle cues regarding when the other person will speak tend to get lost, leading to problems with talk-overs and lags between speakers. This is particularly a problem with larger groups and when significant communication lags are present.

TOOL CHARACTERISTICS

As shown in Table 2, while face-to-face communications are seen as very good for collaboration, they do not generally provide traceability (unless separate recording devices are employed). File transfer, email, groupware and bulletin boards, by comparison incorporate built in traceability. White boards and instant messaging also provide traceability, at least for short periods of time. While face-to-face communication provides a high level of identifiability, this can be more of a problem with other systems. For instance being able to tell who is speaking can be difficult on teleconferences or group radios. Identifiability is generally good with instant messaging, white boards and telephones.

Tool Category	Collaboration Characteristics			
	Time	Predictability	Place	Interaction
Face-to-Face	Synchronous	Scheduled or Unscheduled	Collocated	High
Video Conferencing	Med-High synchronicity	Scheduled or Semi-scheduled	Distributed	Medium-High
Audio Conferencing	Med-High synchronicity	Scheduled or Semi-scheduled	Distributed	Medium-High
Telephone	Med-High synchronicity	Unscheduled	Distributed	Medium-High
Net Radio	Med-High synchronicity	Unscheduled	Distributed	Medium-High
Chat/Instant Messaging	Med-High synchronicity	Semi-scheduled or Unscheduled	Distributed	Medium-High
White Board	Synchronous or Asynchronous	Scheduled or Unscheduled	Distributed or Collocated	Moderate
File Transfer	Asynchronous	Unscheduled	Distributed or Collocated	Low
Program Sharing	Synchronous	Scheduled	Distributed or Collocated	Moderate
Email	Asynchronous	Unscheduled	Distributed or Collocated	Moderate-Low
Groupware	Synchronous or Asynchronous	Scheduled or Semi-scheduled	Distributed or Collocated	Moderate
Bulletin Board	Asynchronous	Unscheduled	Distributed	Moderate
Domain Specific Tools	Synchronous or Asynchronous	Scheduled or Unscheduled	Distributed or Collocated	Low

Table 1. Taxonomy of Collaboration – Part 1

Groupware and bulletin boards may or may not provide identifiability, depending on the system and predefined options. An advantage of many collaborative tools is the wide variety of unstructured communications that they can support. Domain specific tools support primarily very structured communications

INFORMATION TYPES

The degree to which various collaborative tools supports the transmission of different types of information is shown in Table 3. While face-to-face communications can include the transmission of all these information types, different tools are very poor or unable to support the transmission of certain information types well. For example video conferencing is poor for conveying spatial/graphical or photographic information or text (except in very small quantities held

directly before the camera). Audio conferencing, telephones and radios are similarly unable to transmit that type of visual information well and also cannot transmit video information. They are all quite good at transmitting verbal information, however, and can communicate some degree of emotional information (although generally not as well as face-to-face and video conferencing).

Tool Category	Tool Characteristics		
	Recordable/Traceable	Identifiable	Structured
Face-to-Face	No	High	Unstructured
Video Conferencing	Possible	Moderate	Unstructured
Audio Conferencing	Possible	Poor	Unstructured
Telephone	Possible	Poor	Unstructured
Net Radio	No	Poor	Unstructured
Chat/Instant Messaging	Moderate	Good	Unstructured
White Board	Moderate	Moderate or Good	Unstructured
File Transfer	Good	Poor	Unstructured or Structured
Program Sharing	Low	Yes or No	Unstructured or Structured
Email	Good	Good	Semi-structured
Groupware	Good	Yes or No	Semi-structured
Bulletin Board	Good	Yes or No	Semi-structured
Domain Specific Tools	Low	Poor	Structured

Table 2. Taxonomy of Collaboration – Part 2

Tool Category	Information Types					
	Verbal	Textual	Spatial/Graphical	Emotional	Photo-graphic	Video
Face-to-Face	Good	Good	Good	High	Good	Good
Video Conferencing	Good	None	Poor	Good	Poor	Good
Audio Conferencing	Good	None	None	Moderate	None	None
Telephone	Good	None	None	Moderate	None	None
Net Radio	Good	None	None	Moderate	None	None
Chat/Instant Messaging	None	Good	None	Poor	None	None
White Board	None	Moderate	Good	Poor	Good	None
File Transfer	None	Good	Good	None	Good	Moderate
Program Sharing	None	Good (if program supports)	Good (if program supports)	Poor	Good (if program supports)	Moderate
Email	None	Good	None	Poor	None	None
Groupware	None	Good	None	Poor	None	None
Bulletin Board	None	Good	None	Poor	None	None
Domain Specific Tools	Poor	Good (if program supports)	Good (if program supports)	Poor	Good (if program supports)	Good (if program supports)

Table 3. Taxonomy of Collaboration – Part 3

Bolstad, C. A., & Endsley, M. R. (2003). *Tools for supporting team collaboration*. Paper presented at the Human Factors and Ergonomics 47th Annual Meeting, Denver, Colorado.

Conversely, other forms of collaboration, such as chat, white boards, program sharing, file transfer, group ware, email and bulletin boards are very good at transmitting textual information, but very poor at communicating emotional information (despite the use of emoticons) and they can not transmit verbal information. Both file transfer and program sharing can support video collaboration, but only if it pre-recorded. Generally only domain specific tools, program sharing, file transfer or white boards are good for transferring spatial/graphical or photographic information.

COLLABORATIVE PROCESSES

A great deal of difference is seen in the degree to which the different tool types support these different types of collaborative processes (see Table 4). Planning and scheduling tend to require a fair degree of interactivity, making many mediums poorer than face-to-face communication. Groupware, Bulletin boards, instant messaging and file transfer become particularly inefficient for these processes. Dedicated domain specific tools for these functions do quite well however, as they are structured to support the required information.

Tool Category	Processes							
	Planning	Scheduling	Tracking	Brainstorming	Document Creation	Data Gathering	Data Distribution	Shared SA
Face-to-Face	Good	Good	Moderate	Good	Moderate	Moderate	Moderate	Medium-High
Video Conferencing	Moderate	Decentralized Small N	Limited	Limited	Poor	Limited	Good	Medium-High
Audio Conferencing	Moderate	Decentralized Small N	Limited	Limited	Poor	Limited	Good	Medium-High
Telephone	Moderate	Good	Limited	Limited	Poor	Limited	Good	Medium-High
Net Radio	Moderate	Decentralized Small N	Limited	Limited	Poor	Limited	Good	Medium-High
Chat/Instant Messaging	Poor	Decentralized Small N	Limited	Poor	Poor	Limited	Moderate	Moderately-Low
White Board	Moderate	Decentralized Small to Medium N	Moderate	Limited	Moderate (non-text)	Limited	Moderate	Moderate
File Transfer	Poor	Centralized & Decentralized, Small to Medium N	Limited	Poor	Good	Moderate	Moderately Good	Moderate
Program Sharing	Moderate	Centralized & Decentralized, Small to Medium N	Moderate	??	??	Low	Low	Low
Email	Low	Moderate	Limited	Poor	Moderate	Low	Moderately Good	Moderately-Low
Groupware	Poor	Poor	None	Moderate	Moderate	Moderate	Low	Low
Bulletin Board	Poor	Poor	None	Moderate	Moderate	Moderate	Low	Low
Domain Specific Tools	High	High	High	Limited	Limited	High	High	High

Table 4. Taxonomy of Collaboration – Part 4

Brainstorming is also quite hampered in other than face-to-face communication, although some groupware and bulletin board systems can be used to support some types of brainstorming (such as the Adelphi method). While a number of tools can readily support data distribution, most are poor for supporting data gathering and tracking of information as it changes in a situation. Again, dedicated domain specific tools are much better for these types of tasks.

Building and maintaining shared SA typically involves more than just passing bits of data, it also involves sharing one's higher level comprehension of the situation and projections of what is likely to happen, as well as information on one's task status necessary for efficient group task coordination. Due to a higher level of interactivity, video conferencing, audio conferencing, telephone and net radio can do a fair job of supporting these tasks, although in data heavy

environments, only domain specific tools are able to supply the needed bandwidth for transferring the status of many entities and parameters.

SUMMARY

The types of collaboration and communication required within team operations are quite varied. Building a system that can successfully support the collaborative activities present within command and control centers requires a careful analysis of the types of processes and conditions of collaboration needed in that environment. The Collaboration Taxonomy described above provides a first step tool for supporting design decisions in creating team-centric systems. Obviously, selecting only one medium for team collaboration will not meet the needs of most organizations. The ideal collaboration tool will provide the most appropriate medium for collaboration based on the current situation including data type that needs to be shared, number of participants involved and process being performed.

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