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International Conference on Information Systems (ICIS)

2009

Distributed Work Display: A Representation for Analyzing Enacted Distributed Operational Work

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DISTRIBUTED WORK DISPLAY: A REPRESENTATION FOR ANALYZING ENACTED DISTRIBUTED OPERATIONAL WORK

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Abstract

Distributed work is becoming increasingly common, but existing approaches to supporting it focus almost entirely on routine, anticipated processes at the expense of understanding how human actors interact to resolve unanticipated obstacles and misunderstandings. This paper describes the Distributed Work Display, a representation of work as enacted that can support analysts and designers in creating the necessary support for effective distributed operational work. The tool emphasizes the information needed to understand the process of articulation (Corbin and Strauss 1993) or working things out. This representation makes explicit "who knows what, when, where, and how." The use of DWD is illustrated with an example from logistics operations in the US Navy. DWD is compared to other display mechanisms used in practice: email listings, transcripts, and activity diagrams. Based on this comparison we identify the potential value of DWD for analysis of distributed work and design of systems to support that work.

Keywords: Distributed work, Group tasks, Interaction design

Introduction

Modern information systems (IS) have enabled the increasing use of distributed operations to get work done. Distributed operational work is work done by two or more people in at least two different physical locations who are jointly responsible for achieving an objective and must coordinate and interact to make that happen. Examples include logistics, oil drilling, and IS infrastructure maintenance. A critical challenge for participants is to recognize and resolve problems when, inevitably, "stuff happens" as part of daily operations. This challenge is exacerbated when participants are separated in space and time and must rely on technology to connect them.

Distributed operational work, like many other types of work, involves not just execution of planned tasks, but also requires that workers recognize and solve the problems that inevitably arise in the course of doing those tasks. This requirement has been labeled *articulation* by Strauss, also known as "working things out" (Corbin and Strauss 1993; Strauss 1988). People have learned over thousands of years how to do articulation adequately well in a face to face environment. In distributed work people must depend on information and communications systems for support to work together over time and space to achieve goals. However, even if information systems are designed to support distributed task execution, they are not designed for distributed articulation. This has led to unanticipated obstacles to efficient and effective distributed work execution, and has added new issues to the IS to-do list.

In supporting distributed work, information system designers have focused mainly on espoused (planned) tasks, processes, and standard operating procedures (SOPs), but have paid far less attention to enacted work, including articulation. The process representations used by designers contribute to this focus on depicting a process as a typical execution accompanied, at best, by a small number of predictable exceptions. Typically such representations omit the detailed content of communications among participants in a process. We will argue that such details are an important input to understanding the nature of distributed work and how information systems can support that work.

What is needed to better support distributed operations is IS support for articulation. To support articulation, designers first need to understand what goes on in unanticipated operational situations in order to build systems that provide appropriate support. A first step is to understand and evaluate what actually happens when distributed work participants need to work things out in practice. This requires both content and context (Strauss 1993). Content is focused on interactions, and includes message texts, document texts and discussion transcripts. Context includes who is doing the work (role), temporal flow (time), location of participants, the information shared (sent and received) and the mechanism used for sharing the information (e.g. email, voice). This paper describes a tool, the Distributed Work Display (DWD), which represents all of this information and enables analysts to take this first step.

The remainder of this paper is structured as follows: In the next section we review prior work and literature around work representation to motivate the development of the DWD, including a description of IS tools developed and in use for distributed work, thus clarifying the gap that the DWD begins to fill. The following section describes the DWD design. We then illustrate the use of DWD for analyzing an unanticipated problem situation in logistics operations in the US Navy, and compare DWD to other candidate representations in use in practice: email listings, transcripts, and activity diagrams. In the final section we summarize our contributions and discuss future enhancement and application opportunities in practice and research.

Literature Review

Before describing DWD in detail we first look to the literature to see what existing techniques have been or might be applied to the analysis of distributed work. In particular, we will examine tools and techniques for representing the context and content of the interactions among human participants in distributed work processes. Our goal is to identify the capabilities that have been used in such tools and techniques, as well as their limitations for the purpose of analyzing articulation in distributed operations. Our review of the literature will show the need for a representation like DWD to support analysis of distributed work and the design of information systems to support that work.

We begin by examining what might be termed "traditional" process representations: techniques such as activity diagrams which are well established among systems analysts. In reviewing the literature we identify limitations in how effectively these techniques can represent distributed work. We then consider several alternative approaches to representing human activity each of which has the potential to overcome some of these limitations. We will argue that despite the innovations introduced by these approaches there is room for improvement in our representation of distributed work and we identify specific capabilities that we incorporate into DWD to address these needs.

Traditional Process Representations and Their Limitations

Systems analysts have increasingly recognized the importance of being able to represent business processes. Process modeling is important in facilitating shared understanding of processes, managing and improving processes, and developing tools to support processes (Curtis et al. 1992). However, such models primarily focus on an abstract representation of tasks. Such representations are useful in conveying the purpose of a process and a high level description of how it works, but do not capture "descriptive process information:" an account of the process as it occurred (Curtis et al. 1992).

For example, many analysts use activity diagrams (such as the one in Figure 3) to represent business processes (Rumbaugh et al. 1999). Such diagrams can show tasks, control flows, assignment of tasks to actors, and the flow of artifacts between tasks (although artifacts are often omitted from activity diagrams). While in principle arbitrary text can be associated with any element in an activity diagram, such text is normally not included, in part because it tends to make the diagram unreadable. Inevitably an activity diagram focuses attention on the "boxes and arrows" (the activities and the flows among them) rather than on a detailed description of how the work is carried out.

A common feature of many process models is their use of mathematical formalism. For example, the activity diagram is based on the Petri net formalism (Reisig 1985) which itself has been used to represent business processes, especially in connection with workflow and process management systems (van der Aalst 1998). Another well known example is the metagraph formalism which represents work as a collection of tasks which transform inputs into outputs (Basu and Blanning 2000).

Petri nets, metagraphs, and other formal representations offer the possibility of carrying out mathematical analysis or computer simulation of the processes they represent. However, such formal representations inevitably require that actual interactions be reduced to a set of fundamental components such as activities, actors, and resources, with the result that the details of how work is carried out are abstracted away. Such abstractions raise the question of what is omitted in such descriptions of work and whether we have left out anything essential to our purpose in constructing such representations. This issue has attracted the attention of several scholars who have made the argument that the answer to this question is emphatically in the affirmative.

Nardi and Engeström (1999) distinguish between visible work that "yields to being mapped, flowcharted, quantified, measured" and invisible work. The latter includes not only work done by "invisible people" (e.g. domestics) and work done in "invisible places" (e.g. behind-the-scenes) but also the informal work required to carry out seemingly routine tasks. It is this last form of invisible work that is of special concern when seeking to represent distributed operational work, for such informal work is inevitably omitted from process representations which focus on the routine aspects of work. It is only the routine part of the work, that which stays the same each time, which lends itself to parsimonious representation in a boxes and arrows diagram.

As Suchman observes, sometimes the "specifics of how people work" can become very important to the design of systems. "Too often assumptions are made as to how tasks are performed rather than unearthing the underlying work practices" (Suchman 1995).

Sachs (1995) distinguishes between two conceptions of work that are in play when people design systems: the "organizational, explicit" view and the "activity-oriented, tacit" view. The former frames work as a set of defined tasks to be carried out according to established procedures. In contrast, the activity-oriented view sees work as involving a complex set of activities, communication, relationships, and coordination. From this perspective, successful work relies on the capacity of people to identify and solve problems collaboratively. Sachs argues that in focusing on the explicit view, traditional design tends to gloss over the human interactions which are integral to successful work.

Thus, while systems analysts rely on process representations for insight into what people do in an organization, such representations tend to focus on high level descriptions of routine work, and tend to leave out the details of how work is done and how individuals deal with the unusual and the unexpected. These limitations are likely to be significant in the context of distributed work, in which participants may have limited knowledge of how work is done at other locations and yet are affected significantly by such details, especially when the unexpected happens.

Alternative Approaches to the Representation of Work

Some researchers have attempted to address the limitations of existing process representations noted above. We will consider examples of such efforts in three broad groupings:

- Adaptive and dynamic workflow – making information systems aware of and responsive to the non-routine aspects of work.
- The speech act approach – using speech act theory to add structure to communications.
- Richer representations –incorporating rich textual description into process modeling.

Adaptive and Dynamic Workflow

"Workflow systems" are information systems that represent the steps of a business process and support that process by automating the flow of documents among actors as well as providing tools for monitoring and managing the execution of the process. A key premise of the work on dynamic and adaptive workflow is that workflow systems need to be better equipped to handle the unexpected.

Kammer, Bolcer, et al (2000) identify the importance of "managing" discussions among participants related to the coordination of their activities. They identify this as especially vital when "the unexpected happens." They suggest there is value in linking informal communications to particular activities or other elements in a workflow system, something they have done in a prototype. Their approach focuses on computer mediated communication and does not include face to face or telephone communications. The approach also seems to give primacy to the structure of the pre-defined work process as the key organizing principle for making sense of communications.

Bernstein (2000) observes that processes may vary in how precisely the structure of the process is specified. He argues that there is a frontier (spectrum) of specificity and that as one moves across this frontier a workflow system should provide different sorts of support. He has developed a prototype which offers such a range, including: very precise scripts, a list of specific options for the human actor to choose, a list of constraints that the actor needs to follow, and, at the least specific end of the frontier, a display of context about the process. Such context might include shared documents, messages, and task lists. Bernstein is primarily concerned with supporting participants in improvising more skillfully, and thus he focuses on the interaction between a user and the workflow system, rather than on interactions among multiple users.

Klein and Dellarocas (2000) study exceptions – when things do not go as anticipated. They have constructed a knowledge repository of exceptions and the circumstances under which they occur. This repository can be used by designers to identify possible exceptions while designing a process and thus build in mechanisms for detecting, avoiding, or handling them. The approach also includes support for participants, who can use the system to diagnose the specific exception that has been encountered, based on its symptoms, and then get guidance on how to respond. This approach seems well suited to supporting the diagnosis of problems, but to do so the problem encountered must first be recognized as a problem and must be similar to an exception in the repository.

The approaches we have just described share several common features which limit their applicability to an analysis of distributed work. First, all focus on only electronic communication. In the context of distributed work we must often take into account face to face and telephone communications that are not captured by workflow systems. Second, all the approaches we have considered rely on the structure provided by an existing list of process elements such as activities and exceptions. An important goal in analyzing distributed work is to identify aspects of the work which may not yet have the attention of observers, or even of the participants themselves.

The Speech Act Approach

Speech act theory provides a method for analyzing human communications that has been proposed as a mechanism for supporting operations more effectively.

Flores, Graves, et al (1988) take a view of work in which language is central to getting things done. People interact by taking action through speech in the form of *speech acts*. The authors describe a tool called the Coordinator which allows users to exchange messages with each other in the context of a conversation which includes a specific set of speech acts and possible sequences of those acts. By tagging each message with its speech act and putting the message in the context of a conversation the Coordinator makes people aware of the work they are doing and also breakdowns in that work.

This approach occupies a middle space between work as a set of tasks which are treated as black boxes, and work as the free-wheeling exchange of information through a generic communications medium. The Coordinator captures electronic communications but adds structure by incorporating the context of speech acts and conversational sequence.

As has been the case with most of the approaches we have discussed, the Coordinator is limited to capturing electronic communications. By having participants assign speech acts to each communication as it occurs, the Coordinator adds structure without the need for elaborate coding at some later point. However this requires the participants (and presumably analysts and researchers) to adopt the speech act framework and to code as they work.

The CHAOS project explores the same middle ground as the Coordinator but captures additional structure (Simone and Divitini 1999). CHAOS is a system to support communications and coordination as a part of work. The focus is on text and in particular on messages exchanged by participants. Messages are coded as speech acts, in a fashion similar to the Coordinator, but in addition CHAOS provides other methods for capturing context: Actors can be assigned roles, which allows the organizational structure to be captured, and roles can change dynamically. In addition to speech acts, the system can tag messages as pertaining to some physical action in the real world and maintains a repository of such actions (a controlled vocabulary). As with the Coordinator, CHAOS relies on users to add structure to the information captured by the system. Whether this will be practical remains an open question. Again, as with the Coordinator, the data in CHAOS reflect a particular theoretical framework. The tool has been designed to capture and structure data in an operational setting in which the CHAOS system has been deployed.

The Coordinator and CHAOS are work support tools which require adoption by the process participants and some change in their activities. As with the workflow systems described previously, this approach favors electronic communication. In addition, these approaches are not applicable to the analysis of environments in which the tool in question is not installed. That said, speech act theory is clearly well suited to the analysis of human interaction in a distributed work situation. At the conclusion of this paper we suggest that DWD has the potential to provide support for analysis of this kind.

Richer Representations

Our third category of alternative representations groups together diverse proposals whose common attribute is the incorporation of rich description into the representation of work.

Kyng (1995) proposes a set of representations to be used for cooperative design. He identifies the importance of a representation both of work as it exists and work as it could be. The corresponding representations are referred to as “work situation descriptions” and “use scenarios.” Both these representations are textual descriptions. While such descriptions allow capturing the concerns of designers and users with great flexibility they do not focus on the interactions among multiple participants. Instead, the use scenario focuses on the back and forth between users and technology.

Ripoche and Sansonnet (2006) observe that interactions in a “distributed collective” (a kind of distributed work situation) typically involve electronic communications and result in a rich data set. Their focus is on how to analyze that data. They show how the archives of the Bugzilla bug tracking system can be analyzed as a text. Where this analysis focuses on analyzing a single source for the interactions, our goal with DWD will be to incorporate and correlate multiple records of the work process, including transcripts of conversations in several locations. Where Ripoche and Sansonnet annotate the data according to a particular theoretical perspective, our goal will be to represent data in a more general form, allowing researchers to apply a range of theoretical perspectives.

Sack, Détienne et al. (2006) describe a “methodological framework” for studying collaborative design with the goal of understanding the relationship among actors and artifacts. Using the example of the development process for the language Python, the authors identify three “information spaces” – the code itself, documentation of change requests (PEPs), and discussion (threaded email). They analyze the text from the three spaces to develop a map in which actors are linked to the artifacts they interact with and also with each other. This makes visible patterns of communication which can be overlaid on the espoused development process for Python. As with other representations we have discussed, the approach is limited to electronic communications. In addition, each individual actor is assumed to be essentially a separate location. Communication within a location is not part of the analysis, and non-archival communications like face-to-face and phone are not available.

Blandford and Furniss (2006) describe DiCoT -- a methodology including a set of representations for applying the distributed cognition approach (DC) to the design of information systems to support small teams. They identify three themes from DC that apply in this context: physical layout, the flow of information, and the use of artifacts. For each of these aspects of a situation they have developed a set of diagrams and semi-structured text to represent the salient factors. While the paper discusses work taking place in a single location, this approach might be applicable to geographically distributed work as well. DiCoT provides a detailed accounting of the physical layout within a location as well as the role played by various artifacts. DiCoT focuses on the pattern of flow: who interacts with whom, but does not represent the contents of these communications. With DWD our concern will be to identify the physical separation of actors into multiple locations and to represent the details of what is communicated among those actors.

Summary

In summary, many researchers have identified the importance of representing the details of how work gets done. A number of systems or techniques have been proposed for addressing this issue. These systems include those which add some flexibility to existing workflow systems, those which capture and structure electronic communications, those which analyze electronic archives (communication, source code), and those which describe interactions between users and systems.

In reviewing these systems, we identified two additional capabilities, not found in any of the representations we reviewed, that would be desirable for the effective analysis of distributed operational work. First, existing systems focus on electronic records of communication and often use a single source of such data. We see the need to also capture ephemeral communications such as face to face conversation and to capture such communication in the multiple locations involved in a distributed process. These multiple sources also need to be correlated so that analysts can determine the unfolding of interactions in multiple locations over time and so that they can determine which information was available in each location. Second, existing systems tend to structure descriptions according to a preconceived scheme, in some cases a particular theoretical framework and in others an existing map of the espoused process. We see the need to allow analysts greater flexibility in their analysis so that they can determine which communications should be grouped together and how they should be analyzed. In addition to these capabilities, our review suggests the possible benefit of employing a tool which is agnostic as to which theoretical framework ought to be employed in the analysis of distributed work.

These requirements suggest the need for a new approach to representing distributed work. DWD has been developed with these issues in mind.

The Distributed Work Display

To understand how distributed work is actually done requires the ability to analyze both the content of the work (e.g. messages sent and received, documents produced) and the related context: who did the work, when did they do it, where were they located, what information did they know, what might they have known (Corbin and Strauss 1993). As will become evident below, a standard log, such as an email thread listing, provides mainly content, and is not set up to illuminate the context. Process models such as activity diagrams convey an abstract depiction of context and content, but omit a detailed description of what actually takes place. Transcripts provide a text of what took place, but are difficult to use, especially for multiple near-simultaneous conversations across locations. The Distributed Work Display (DWD) provides relevant data about the actual situation, in terms of both content and context, in an easy-to-understand format that highlights the salient features and potential issues. This display can then be used for further theoretical or practice-driven analysis or design.

DWD History

The DWD was developed as part of a project with the US Navy to test and analyze distributed operations processes, specifically, distributed shipboard logistics (Quaadgras 2009). The Navy's goal in moving to distributed operations was in part to reduce logistics staffing aboard ship by 80%. The Navy tested this new environment in a week long land-based simulation designed to study how personnel in these new distributed roles reacted to various situations, both routine and unplanned, designed by experienced logistics officers, and to investigate how the distributed nature of the work impacted the problem solving process.

The simulation consisted of three groups of professionals, (the ship, operations, and administration) located in three rooms with both synchronous and asynchronous communications options (in this case, Walkie-Talkie and email). Each group was given a general scenario, accompanied by room-specific assumptions and events. The groups then had to work together to execute the relevant logistics processes and solve the stated problems. Scenario examples included responding to a thunderstorm delay, ordering extra food while underway, fixing a broken scullery, and finding a way to offload excess ammunition. The data collected consisted of transcriptions of the voice recordings made in each room, as well as the text of scenario inputs and emails written by the groups.

DWD Representation

The DWD uses written text, such as transcriptions of conversations and records of email or instant messages. For this reason, audio data is transcribed and annotated with codes added for relevant sounds (e.g. laughter, interruptions, and Walkie Talkie use). In addition, reference codes are added for emails referred to in conversations based on comparisons of the conversations with written emails. Transcript text is manually filtered to focus on conversations related to the situation being analyzed – what Goffman calls strips - slices from the stream of ongoing activity (Goffman 1974).

To understand and use this data for analysis, one of the key issues is to understand the context: "who said what to whom when where and how" and "who heard or read what from whom when where and how." This is difficult to see when data consists of hundreds of pages of transcribed text, especially when each text document reflects only one of several locations, and when emails are in yet another format. The Distributed Work Display addresses this by representing both the spoken text, as well as its source (person and room), destination (person and room), timing, and whether it was created or used by a process participant or an exogenous actor. An example is shown below in Table 1 based on a short section of transcribed text and related emails. This display includes the following elements:

- Elapsed time in minutes and seconds, is shown vertically (①),
- Locations are listed horizontally across the top of each column (e.g. ②). Columns labeled 'xx' to 'yy' indicate that the cell's contents are from a member of 'xx' to a member of 'yy' and are available to both simultaneously.
- Speakers' names or roles are abbreviated ③
- Brackets ("[medium]") are used to denote the medium of transmission: [sync] or [async].
- [sync] indicates synchronous communication ④that is audible in both locations simultaneously, for example a phone or Walkie-Talkie conversation.
- [async] indicates asynchronous communication, such as email text in this example, is marked [async] and is shown in the appropriate column (sender to receiver) based on the time sent ⑤. Each email is also labeled with a unique code, for example c013, for reference in later communications. Asynchronous communications may be received and read at any time after they are sent.
- Parentheses with italicized text ("*italics")* are used to indicate transcription or other clarifying information ⑥.
- Attachments are labeled with the relevant code and are hyperlinked ⑦.
- Color coding of the columns is used to indicate location. In the example below, blue denotes SHIP, red denotes OPS, and purple (blend of blue and red) indicates the two columns in between (SHIP to OPS and OPS to SHIP), whose contents are available to both locations.
- A column for exogenous information transmitted to or from a location is colored in a lighter version of the location color. For example, light blue is used below for exogenous communications in the SHIP location.
- A dashed line between columns separates the two sides of a communications link (such as SHIP to OPS and OPS to SHIP)

Table 1: Sample Distributed Work Display Illustrating Key Features

Time ①	**Exogenous to SHIP**	**SHIP**	**SHIP to OPS** ②	**OPS to SHIP**	**OPS**
06:54			SO: ③ [sync]④yeah this is LCS hey we have an overage of 2 57 mm rounds.		
06:59				AMMO: [sync] ok	
07:00			SO:[sync] and we have no room for 'em and we'd like to make sure ⑥(*pause*} that these are		

			offloaded.		
13:35	⑤ [async c013] **From** 2nd Fleet: need to get u/w early AM due to only break in weather. Keep what you have onboard. ⑦ [c018 attached]				

Example and Comparison with Other Representations

In this section we provide an example showing how DWD supports understanding distributed work operations in a specific situation, and compare it to three frequently used representations: email, transcripts of conversations, and activity diagrams. For each representation we discuss when an analyst would consider using this representation, and provide an indication of the kind of analysis which might result from the use of this representation. Based on our analysis of each representation's text from a content perspective, we show that each representation provides a potentially different perspective on the specific situation, and we clarify the particular benefits of the DWD representation. We end this section with a brief comparison of the advantages and limitations of each type of representation for the description of distributed work, based on the articulation information each representation emphasizes.

The example, taken from the Navy project described above, documents a particular enactment of ordering food for a ship. Frequent ordering is needed because the ship can only carry 21 days of food. Thus one of the jobs of the cook (CSC) is to ensure a sufficient supply, and to make use of every port visit to increase that supply. The expected process is thus that sufficient food is ordered on a regular basis, depending on the port visit schedule, which may change unexpectedly.

In this example the ship's cook (CSC) requests additional food to be delivered to Nassau, outside of the standard ordering schedule. OPS translates and forwards the information message to the supplier, and the supplier raises some questions about delivery directly to the ship, which the ship answers. The ship's cook then sends an additional email attempting to clarify his intent (topoff vs. full load), which is countered by OPS.

Representation 1: Email Listing for a Distributed Work Situation

Although email is not a typical data analysis model in most research, analyzing the content of emails is common in practice, for example as part of the legal discovery process (Britt 2005). Most of the work in this example situation is accomplished via email so that an analyst might choose to represent the work using an email listing as shown in Figure 1.

The email listing below starts with a request for a topoff from the ship, but provides no specific reason. The request is translated as full load by Ops, who orders a full load of food from the supplier. The supplier requests the delivery location (which was not provided in the email from the ship) and this is provided by the ship. Then the ship sends what appears to be an addendum to the original request, suggesting that topoff is not the same as a full load. Ops replies that topoff means a 21 day cycle menu.

Figure 1: Email Listing for Food Topoff

From: Ship (10:37am)
To: Ops
Message-ID: C016
Request full top of food on 14th of stores. Request stevedores for onload. CS2

From: Ops (10:44am)
To: Supplier
Cc: ship
Message-ID: C015
Food provision request FFV & dry menu cycle 1-21 on the 14th. Request stevedores for onload.

From: Supplier (10:45am)
To: Ship
Message-ID: C025
please provide place for delivery?? In Norfolk?

From: Ship (10:46am)
To: Supplier
Message-ID: C026
deliver to pier #2 NOB. Stevedores confirmed

From: Ship (11:12am)
To: Ops
Message-ID: C014
The request is for food topoff on the 14th mar. NOT 21 days load. CS2

From: Ops (11:18am)
To: Ship
Message-ID: C127
CS2 when you say top off it means 21 days cycle menu. CSC.

This email trail by itself does not explicitly identify a problem – but this interaction eventually results in $7000 of food left on the pier in Nassau. Why did this happen? To answer this, an analyst needs to ask a few additional questions: What really happened? Why did the ship request a topoff; what did the ship mean by topoff, if not full load; and what are the implications of this incongruence in meaning between the ship and Ops?

The email listing reflects that there is an issue relating to working out the definition of topoff, but does not indicate the potential seriousness of the issue, nor the context that led to the discrepancy in definition. Email is useful for representing roles and disparate locations, but is not structured for providing neither detailed context nor task division, nor for separating out expected versus unexpected issues.

Representation 2: Transcript of a Distributed Work Situation

Transcripts are used in many types of qualitative research (Patton 2002). An analyst might use this representation when the conversation surrounding a set of tasks may provide clues to why execution occurred as it did.

Figure 2: Partial Transcript for Food Topoff

1:30	SO	CSC, about the food, when do you want to do it?
1:40	CSC	O we got it, we're fine, we don't need food. We're only gonna be there, I mean it's 8th to 11th. But we're gonna depart on the 15th. Let's schedule a food topoff for the 14$^{th.}$
Time gap....with text irrelevant to example		
4:05	CSC	yeah, request full food topoff for march 14th and stevedores requested for Nassau. [dictating c016 to CS2] I don't know what else to say.
Time gap.....with text irrelevant to example		
5:05	CS2	requesting food and what else?
5:10	CSC	stevedores

This transcript summary shows the conversation between SO, CSC and CS2 onboard the ship leading up to the first email requesting the food topoff. However, since emails are not a standard part of a transcript and since the transcript is from conversations at a single location, this example cannot be displayed in its entirety. It is clear that CSC does not make detailed location information explicit. It is also clear that the email is not a standard form for requesting food, and that the topoff order is not a standard request: knowing that a full food order is for 21 days, the conversation makes clear that the topoff request is not a for a full load but a request for five or six days, as they don't need food today (the 8^{th}). This conversation begins to address the reason for the final two emails in Representation 1 above.

A transcript can be a useful tool for analyzing conversations: it focuses on enacted work activities and represents the process of working things out as it happens for each case (as long as this process is reflected in the audio). However, it is incomplete for representing a distributed work situation as it omits the email communications as well as any conversations taking place at other locations.

Representation 3: Activity Diagram of a Distributed Work Situation

An analyst might use an activity diagram (Rumbaugh et al. 1999), described in the Literature Review section, above, to focus on the relationship of expected tasks, roles, and control flows, for example to determine if tasks were missed, duplicated, or changed. The activity diagram shown in Figure 3 below was constructed to reflect the standard operating procedure for requesting a food top off. The diagram focuses on the expected sequence of activities but also provides for some flexibility in how the process unfolds by allowing for the possibility that the supplier and the ship's cook may need to exchange several messages to clarify the nature of the request.

This diagram explicitly shows the roles of the participants, and the messages that may be exchanged between them. It shows that to order food, a request is made by the ship, which is responded to by Ops via another request made to the supplier. This second request is copied to the ship, represented as a confirmation of the request by Ops to the ship in the activity diagram. The diagram also shows that if the supplier requires additional information, an additional request can be made by the supplier, and replied to by the ship. However, the content of the requests and replies, and thus the reason for the additional request/reply step, is not available in this representation. This diagram fits the email exchange from Table 1 quite well, except for the last two emails. These are not represented in the activity diagram, as there is no planned 'disagree' activity.

An activity diagram is a common process and systems workflow design tool, making it potentially a useful representation for distributed work. However, it is used mainly for planned (espoused) processes, and for that which is predictable. Thus, while an activity diagram makes roles and communication channels explicit, and highlights the expected tasks, it is not well suited to displaying the actual tasks that are done, nor the errors, corrections, and adjustments made in the 'working things out' process that accompanies task execution. That is, an activity diagram assumes control flows are handed off without problems, that every task can be accomplished by the person assigned to a particular role without describing further how it is done, and it assumes that requests and messages are unambiguous and that syntax and semantics are correct and understood in the same way by both parties to a communication.

Representation 4: DWD of a Distributed Work Situation

The DWD in Table 2, below, combines the email and transcript information from Figures 1 and 2, and displays it in a way that highlights the contextual variables of location, communication channel, and timing. Roles are made explicit in each cell by indicating who speaks, sends, or receives the message. The DWD focuses on the enacted situation, not the espoused process.

Figure 3: Activity Diagram for Food Topoff

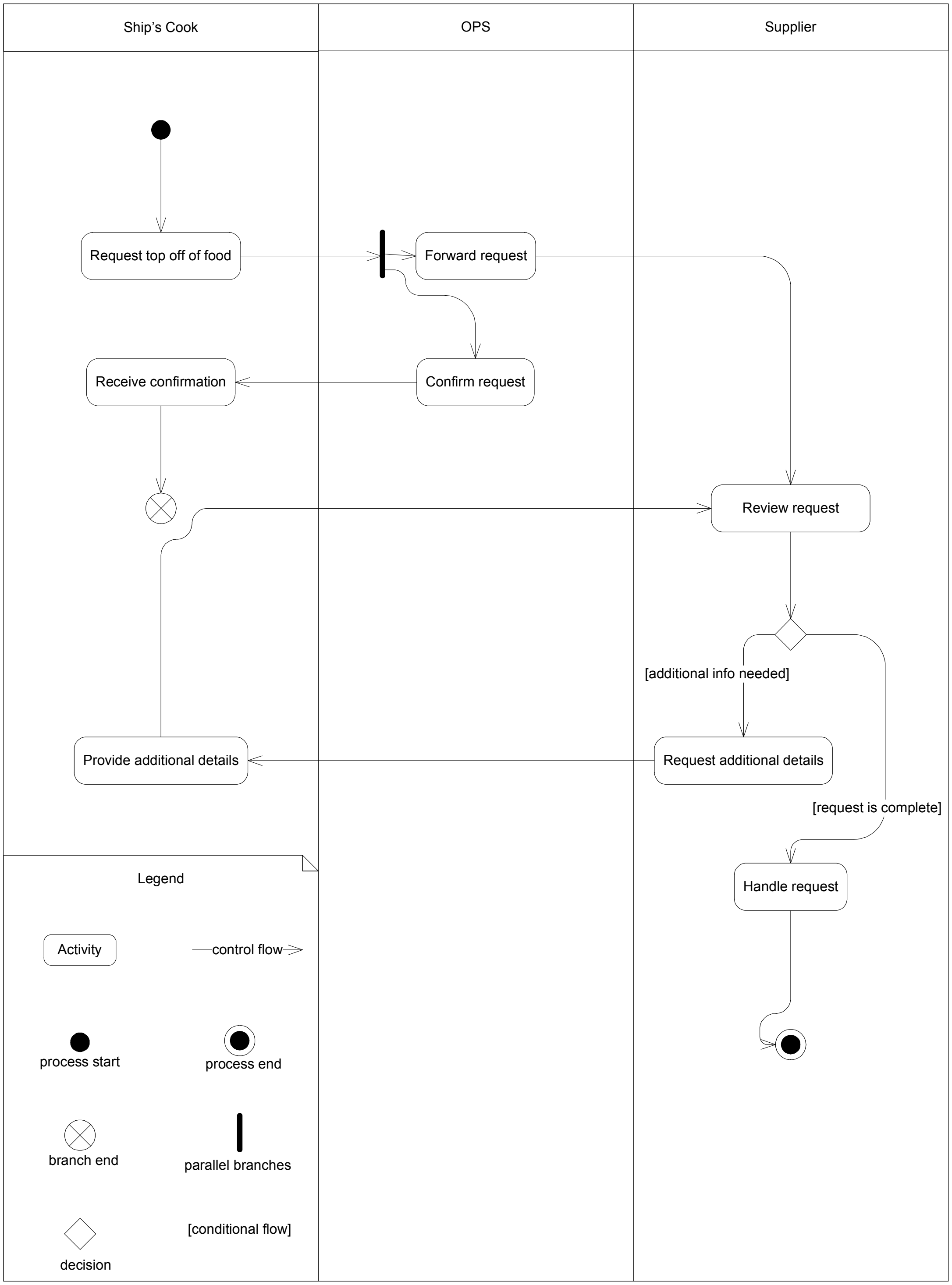

Table 2: DWD for Food topoff

Time	Exogenous Supplier	Ship	Ship to Ops	Ops to Ship
01:30		SO: CSC, about the food, when do you want to do it? ①		

Time	Exogenous Supplier	Ship	Ship to Ops	Ops to Ship
01:40		CSC: Oh we got it, we're fine, we don't need food. We're only gonna be there, I mean it's 8th to 11th. But we're gonna depart on the 15th. Let's schedule a food topoff for the 14th.		
04:05		CSC: yeah, request full food topoff for march 14th and stevedores requested for Nassau. *(dictating email c016 to CS2}* I don't know what else to say.		
05:05		CS2: requesting food and what else?		
05:10		CSC: stevedores		
10:00			② [Email c016]: From SHIP to OPS: subj: top off stores. Body: Request full top of food on 14th of stores. Request stevedores for onload. CS2	
17:00				③ [Email c015]: From OPS to Supplier, cc SHIP: Food provision request FFV and dry menu cycle 1-21. Request Stevedores for onload. [c016 attached]
21:12	④ [Email C025] **from Supplier** to SHIP: Please provide place for delivery?? In Norfolk? [c015 attached]			
22:15	⑤ [email c026] **From** SHIP **to Supplier**: deliver to pier #2 NOB. Stevedores confirmed [c025 attached]			

Time	Exogenous Supplier	Ship	Ship to Ops	Ops to Ship
33:35		⑥CSC: wait a minute… *(Reading c015*} we don't want days 1-21, we just want the days that are missing. If they send us a full onload, we just need a full topoff. That's what we said, topoff.		
44:45			⑦Email c014 (reply to C015) from SHIP to OPS: The request is for food topoff on the 14th Mar, not 21 days load.	
52:20				⑧Email c127 from OPS to SHIP: CS2, when you say top off it means 21 days cycle menu.

The content of the DWD in Table 2, above, provides a more complete representation of the situation: the ship's CSC (cook), responding to a comment about sufficient food ① by SO, the ship's supply officer, recognizes a potential problem: he may be short of food in the near future, although he has plenty now. In response, he decides to order a food topoff, in order to leave Nassau with a full load of food five days from now; this motivation is made clear by the discussion he has with the CS2. He sends an email to Ops ②. Based on receiving this email, the Ops CSC believes that the ship needs a full onload of food – 21 days' worth, as evidenced by his request of this amount of food to the supplier, and copies the ship ③ via email C015. The supplier reads the email, accepts the requirement for a full load, but realizes she does not know exactly where to deliver the food, so asks the ship directly ④. The ship supplies this data ⑤. Based on receiving the copy of the Ops note to the supplier (c015), the ship's CSC recognizes that Ops mistook their request for topoff to mean a full load ⑥. The ship emails Ops about the discrepancy (email c014 ⑦). Ops reads that note but ignores the discrepancy: he tells the ship that topoff means full load. (Email c127⑧). The result is that the order stands, and five days later 16 days' worth of food is left on the pier in Nassau, as there is no room for it on the ship.

The DWD provides a more complete representation of the distributed work situation, including both the tasks and the articulation processes that were used to work out the issues related to the execution of this task: the definition of topoff and the requests and replies relating to delivery information. None of the other representations above provides all this important information in a readily usable display format.

This example of articulation issues clearly shows that misunderstanding around the meaning of the word topoff caused the $7000 error. Analysis of additional examples resulted in specific practice recommendations to increase training around the articulation process. Such training would include issues such as the importance of clarity and completeness of message transmission. However, the training would also go beyond tasks and standard operating procedures to focus on the necessary interactions around creating and validating shared understanding, and explicitly coming to agreement about the situation and potential consequences (Quaadgras 2009).

Comparison of Relevant Information Availability Across Representations

Table 3, below, summarizes the types of information needed to understand how distributed work is enacted – both the tasks as well as the articulation processes used to work things out, and shows which types of information are typically available in each of the four representations. This comparison shows that DWD can provide the information needed to help to clarify the issues participants face when working things out in a distributed situation, and can thus provide guidance for solutions, whether via training, process changes, or system support options.

Table 3: Information Available From Various Representations of Work

Information about:	Email	Transcript	Activity diagram[1]	DWD
Temporal flow	yes	yes	expected sequence	yes
Location information	in header info	no	no	yes
Role information	in header info	in speaker name	yes	in speaker name
Communication channel	no	no	no	yes
Tasks required	no	no	yes	no
Tasks executed	some	some	no	no
Articulation processes used	some	some	no	yes
Communication boundaries	no	no	no	yes
Spoken text	no	yes	no	yes
Written text	yes	no	no	yes

From the table it is clear that email text provides some useful information, but misses much of the context from which errors arise, including issues or limitations around communication channels and boundaries, misunderstandings, or issues caused by delayed, misdelivered or misunderstood messages.
Transcripts provide much of the raw data about the articulation used, as well as rich context. However in distributed work it is difficult to compare transcripts across locations and to account for the impact of time and time differences. In addition, without filtering, a transcript usually contains a great deal of extraneous information.

Activity diagrams provide a concise representation of roles (swim lanes) as well as tasks and relationships among tasks. However, like most process-based diagramming techniques, they focus on espoused or typical rather than enacted (actual) activities. That is, no details of actual work are included. In particular, activity diagrams have no mechanism for including articulation activities, especially if these are unexpected. In addition, the need for readable activity diagrams tends to invite simplification which may move the diagram toward an idealized view of the work.

The DWD shows context and flow unambiguously, as well as location, timing, and roles. These features make it relatively easier to see the issues and misunderstandings as they arise, as well as their potential implications. This makes it possible to use DWD to analyze articulation, which in turn can help to develop IS support for this very real but underutilized mechanism for successfully accomplishing distributed work.

Conclusions

In this paper we have argued that it is important to understand how distributed work actually occurs, especially with respect to articulation: the management of unanticipated situations such as problems. This requires new representations for describing and displaying how distributed work is done. To fully understand articulation in distributed work, and to design appropriate IS-based supports for these processes requires analysis of a combination of content and context elements, displayed in an easy to use format for analysis. Content includes messages, documents and conversation transcripts, while context includes roles, times, locations, communication mechanisms, and communication channels. DWD, unlike other tools described in the literature, provides all of these, which will lead to improved design of the supporting information systems environment.

The IS community has enabled distributed work through technology, and business is adopting it at a rapid rate, for very sound reasons, but distributed work is creating new issues, problems, and situations that are not at all well

[1] An activity diagram using the full range of permissible notations could provide information needed to understand articulation; however this is not how activity diagrams are typically used and so is not further discussed here.

understood, especially when unanticipated situations arise alongside the planned tasks. Given that by definition distributed work requires IS support, it is incumbent upon IS researchers and practitioners to provide and use the tools that will support better design by providing a more complete representation of the work as it occurs in practice.

DWD Limitations

DWD is currently constructed based on transcribed auditory conversational text and email archives. Thus visual cues are missing, and it is not always clear to what exactly a participant may have been referring. In addition it is not always possible to transcribe every word, due to extraneous noise, people speaking at the same time, and accents.

Some limitations of DWD are scale based. Currently DWD is hand-created; it is dependent on the availability of transcripts and requires manual piecing-together of conversations and related communications, whether synchronous or asynchronous. With additional experience as well as more sophisticated speech to text and text analysis tools, some of the initial work may be automatable. However, issues of framing, extraction, and emphasis will require continued attention of human analysts in preparing a DWD.

DWD deliberately omits any prescribed method of analyzing the resulting display. While this has the advantage of supporting many types of research, it does leave the analyst with no standard analytical process that lends itself to readily developing conclusions or design support. This issue can be resolved through further research on the viability of various analytical approaches.

Further Work: Uses for DWD

Given the richness of the DWD representation, it can be used for a variety of analyses both for practice and for research. Practice uses include: after action reviews to understand the causes of errors and costs overruns, monitoring to prevent errors and cost, and design of processes, information systems, and governance mechanisms to better support distributed articulation as it happens. DWD could also be applied in supporting DiCoT Speech Act Theory-based analysis, or the development of formal process models such as Petri nets. It has already been applied to support development of theoretically driven models of problem recognition in distributed work (Quaadgras 2009).

One interesting potential complement to DWD is the generalized commitment machine representation proposed by Singh (2007).This approach shares the formality of Petri nets and metagraphs, but includes a representation of the commitments actors make in the context of a process. This allows for variations in the actions taken at any point in a process based on the state of the commitments involved, and allows for the possibility that commitments may be renegotiated as the process unfolds. Since this representation requires the explicit identification of the kinds of commitments that can be made in a process, DWD may be an important tool for identifying such commitments.

Research questions that DWD based analysis can support include: how does distributed work get done under various conditions? How does the use of different organizational structures, work practices, and information influence distributed work execution and performance? DWD may also prove useful in developing theoretical explanations for observed phenomena related to distributed work.

Additional analyses of distributed work in practice can show how frequently various types of exceptions occur, thus focusing the search for IS support solutions. In the Navy project over 80% of the 100 posed problems required articulation that was not part of the standard operating procedures. In addition, the Navy evaluators judged that 52% of the posed problems were not resolved as expected. Articulation episodes ranged from simple verification of information, to more complex discussion of alternative interpretations, and a need to evaluate and execute multiple actions when initial attempts to resolve an unexpected situation caused additional problems, most of which were due to articulation failures. One example of a future area of interest is in analyzing logs of oil drilling activities to discover patterns of interaction difficulties among operators and engineers and creating better support mechanisms.

Although creating a DWD is currently a somewhat labor-intensive procedure, the ability to explore how distributed work is enacted, and to design and test supporting tools and environments is key to minimizing operational risks and costs, and maximizing the effectiveness of distributed operational work.

In conclusion, distributed work is becoming more common and is increasingly used for less routine, more risky, and thus potentially more costly work. Therefore, we need to be able to represent what actually happens far more accurately in order to review problems, fix problems, support problem management, and ultimately, prevent problems or at least reduce their impact via real time information system support and system design. DWD is a first step in creating this necessary representation.

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