

Supporting the Flow of Information Through Constellations of Interaction

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Abstract: In field studies designed to uncover opportunities for computationally-intensive business applications, we observed an interaction pattern we term "constellations" in which people depend on a variety of people and information sources to perform the duties of their employ. Constellations are significant for several reasons. Constellations extensively cross organizational and corporate boundaries, the value of a constellation depends on the individual being appropriately *in sync* at any one time with the elements of the constellation, constellations are uniquely defined in terms of the individual who draws maximum benefit from that particular collection of people and information, and the value from a constellation derives from all of the elements existing in a particular work context to support the individual who is the hub of the constellation. From a design perspective, the implications are for CSCW technologies that do not assume well-defined organizational and corporate boundaries, but rather that support individual access to and management of personal connections and interactions.

Introduction

In the past few years, much has been said about the value of studying actual practice in context to inform the design of computer technologies (Blomberg et al, 1993; Holtzblatt et al, 1993; Hughes et al, 1994; Plowman et al, 1995; Shapiro, 1994). Such methods in the high tech industry provide a closer look at actual user activity and the ways in which novel technologies might support those activities (Lewis et al, 1996) However, unlike traditional ethnographic studies, the intent

here is not so much to seek general principles about society but rather to identify data that is applicable for design. Such studies are one way of identifying opportunities for new technologies. For a business that knows its general area of interest but has flexibility in its product range, studies of real world work practice can be an excellent method for eliciting opportunities for designing new products.

In the work reported here, our goal was to identify opportunities for business applications that take advantage of today's computing power. We set out two phases of field work: first to explore a range of domains and work activity that already use intensive computational power and second to observe current business practices that might utilize more computing power, particularly as drawn from experiences in the first exploration. Our goal was to translate the work activity into design ideas.

Our basic finding suggested that not only did people rely on their computing power for their jobs, but more significantly, they relied on interactions with other people and information sources to at least as great an extent. Specifically, we identified a persistent pattern of such interactions that we call *constellations* as sets of people and information sources connected to a specific individual, which cross organizational and corporate boundaries and which exist in a particular work context. That is, constellations differ from personal "networks" in that the people and information sources provide value in an immediate and specific context, and constellations differ from teams in that the constellation members may not know each other and only contingently share common goals.

The purpose of this work was to identify new opportunities for computing power. However, examining our data through our "designerly eyes" (Henderson, 1993), we see constellation interactions not only as a major aspect of accomplishing work but also as an opportunity, and indeed a need, for CSCW technologies to recognize these interactions. These interactions demonstrate a need not to support teams (viz. groupware) or personal networks (viz. personal information managers—applications and processes that view the individual either in isolation or as merely a part of a formal organization—but rather to support constellations. Specifically, low-level system architectures too often assume a fixed, a priori arrangement of access to people and information, focusing largely within organizational boundaries and limiting the ability of an individual to access, manage, organize and view ever-changing information in a unique constellation from an individual work context.

In the following paper, we describe the field work, give examples of the interview data, and suggest the relevance of our study for design of CSCW technologies.

Study Plan

Our primary goal in the study was to gain an understanding of the ways in which intensive computing power supports an individual's work. Thus, we wanted to get broad exposure to a variety of work environments and tasks in the first exploratory phase of our study. We interviewed 25 participants in five organizations using open-ended questions about their work, their tools, and their interactions

Participants

We chose organizations and participants within those organizations based on work that would utilize computing power. We brainstormed a list of tasks that would need intensive computing such as multimedia applications, image processing, and simulations. From our list, we choose areas of rapid information summarization, large data sets, and complex calculations as those most relevant to the business environments and computing intensive application focus we needed. Our domains for study were a government scientific laboratory, a bank equity trading department, a division of a government intelligence community, a high-tech product business, and a service that provides research findings to elected officials. The duties of our participants included stock traders on a trading floor, portfolio managers, scientific researchers, market researchers, a branch manager, expert consultants, information analysts, and people whose job it is to collect information from far-ranging sources.

Method

We scheduled 1 to 1 1/2 hour unstructured, observational interviews with each of our participants in their work environments. With the exception of the three buyers on the stock market trading floor, we interviewed participants individually. Two interviewers were present. Our data consists of audio tapes and transcripts, notes, and occasional still photographs.

Our questions were initially open-ended to the extent that we asked two primary questions: 1) What are your responsibilities? 2) Describe in detail a recent project on which you've worked. From each of these, we used artifacts in the work environment and further questioning about tools and sources of information to determine who, what, why, how, where and when work was accomplished to the extent that interview time permitted. Questioning was guided by our ultimate purpose: to understand their environment sufficiently to develop useful computing concepts.

Data Interpretation

With our data, we were looking for emergent patterns that cut across all or most of the interviewees in the sample. In fact, we were specifically trying to build a model for our data that we could then use to derive useful product concepts. That is, as practitioners, we were not intent on representing our subjects' experiences in their own terms, but rather we focused on identifying an appropriate transformation of the data that retained the context and veracity of the subjects' experience but which is useful for designing computing products. An example of this approach is represented in Mateas, Salvador, Scholtz and Sorensen (1996).

In this particular case, we were looking pointedly for new uses of computing power among information and knowledge workers. Thus, we were looking for a common model to describe the data as well as one that would make sense to designers and engineers. The constellation interactions was an emergent pattern among all the interviews. And, in fact, all of the subjects' individual environments can be viewed through constellation lenses. However, from the perspective of each user, the constellation model might not best explain any one subject's environment. It is important to note that the constellations emerged as an opportunity for design rather than as a careful description of the work environments.

Specific examples of our data illustrate our observations and the emergence of constellations.

Dwight the Physicist

Dwight's job is to perform complex numerical calculations to help define the flexibility and limits of a multi-national agreement for monitoring underwater nuclear tests. Dwight describes his work as very computer-centric.

D "...Most of my time is spent sitting in this chair. I've shifted gradually into doing computer simulations of physical phenomena...another way of describing my work is that it focuses on shock waves and hydrodynamics. Most of the time in my career I've been using the Crays because that was the place for a long time, the only place where you could get lots of good CPU time and the Crays are still faster by an order of magnitude than anything we do on our regular computers...."

However, we quickly start to hear ways in which Dwight also depends on others

D: "... And we have what's called a boundary condition in an attempt to try to understand that surface. If - imagine hypothetically, though, I could shift from a condition which I ignored the waves to another one in which I simulated the waves. One of the results might change a little bit or maybe even quite a lot.

One of the things that I'm supposed to be doing that's a major part of the requirements of my job is to know when I'm going to get into a situation where things are going to change drastically.

T "So you're looking for one of the prime effects on the wave? Well, what conditions you have to pay attention to -

D: "Yeah, that's right. And some combination of knowledge and experience *and talking to other experts to know what's critical and what's unimportant*. This plot here, which you can have a copy of if it matters, is an example of what I'm calculating. Energy total means the energy in the wave. This is time and you see there are several different lines here. They all come down - this is a log scale here so they drop a lot. This is from original energy represents *perhaps 10 tons of explosion*. It's *dropping in order of magnitude about here*, but interestingly, these calculations represent finer and finer zoning *and as John pointed out, it's getting so that this last one is almost level and in fact the calculation represented here may form, should form another line that's out about here, closer to level*. So the point is that I do repeated calculations of something. I can't take the first calculation and assume that's the answer, I have to do repeated calculations. ..

Dwight works in a small group of other scientists, particularly with John, as their work often has similar goals which enables them to look at, understand, and comment on each other's results. That is, Dwight and, in this case, John, are not simply colleagues, but colleagues who at this time are sharing the ongoing context of the work they are doing. Further, Dwight is specifically working with John in this example, and John is in the same organization as Dwight. In this regard, Dwight also mentions regularly interacting with his boss and his assistant post-doc. All of this seems rather straightforward.

However, we also learn that Dwight is responsible not only for his own work, but for certain input to the multi-national task force. That is, Dwight needs to understand where his research intersects with the test ban treaty negotiations especially when it comes to offering technical details for the decision making. Dwight has contact with certain individuals who are responsible for bringing Dwight's work into their discussions and on whom Dwight relies for knowing the requirements and context for his work.

D. "...but my stuff feeds into a study to try to understand if the explosion occurs here, how does it propagate and what do these things, which might represent barriers, like for instance right here is a very significant barrier .. "

In addition to the content of his work, Dwight depends on understanding the software he uses to calculate the simulations of physical phenomena. In this case, the primary wave code he was using for this work at this time was written not by him, but by someone else at a different organization. Dwight knows the author, and they have interacted frequently and, again, in the context of the actual work. Dwight refers to him casually, as if he were an obvious member of the "team".

D: "Yeah, well because of the fact that Andy's at NRL he gave us a version of [the code] and we've been making mostly quite minor changes to it."

Other pieces of code were written by people in other divisions in the government laboratory where Dwight works.

D. "Well, in solar luminescence the guys in [another division] we're dependent on. But one of the nice things for me personally is [the wave simulation code] is almost entirely self-contained and if Andy fell under a truck why we could manage pretty well. Now that's not true of the typical code effort around here where usually one organization or one group is developing a code and other people are using it. And there's all sorts of psychological

questions about whether or not you're close to the developers either psychologically or physically. For instance, it's a real hassle if you can't discuss anything about the code over the telephone...*If I want to just ask something pretty simple about how do I get this plot, I can call somebody.* But still they're over on the other side of the lab. Annoying. And it tends to be that they tend to do things *when they make an update or an improvement they tell the 2 dozen other people in their hallway and we never hear about it.*

In fact, Dwight continually works to understand the code and to maintain his "in sync'ness" with that element of his constellation. Notice also that Dwight wanted to discuss not the code per se, but the result of the code in the form of his particular plot. This implies that Dwight is not necessarily interested in code the same way in which the developers would be interested. In fact, Dwight's issues with the code reflect the value *he* gets from the code, i.e., his perspective, rather than the perspective of the developers. Thus, his particular issues may well force the developers to evaluate their work in Dwight's context.

In this particular example, we also see a case of non-reciprocity. While Dwight holds these people in his constellation, the others clearly do not consider Dwight to be a part of theirs—at least not to the extent that they would provide him updates, etc. The value relationship is one way; Dwight is primarily interested in the code because of the plots that he can produce, i.e., his perspective. Furthermore, the value Dwight is drawing from the developers is mostly unilateral.

Dwight routinely depends on a variety of people and information sources on a regular basis: John and others in his group provide feedback on results, his manager provides direction and priorities, simulation code experts (from two different organizations) provide specifications and constraints of the software, expert colleagues (both collocated and physically separate) provide knowledge about boundary conditions on the simulation, and the US negotiating team members provide insight into the committee perspective and needs. Note further that Dwight needs to stay in sync with all of these people only to the extent that his current project continues, i.e., so long as he remains in the current context. These people are not on the same "team" as Dwight, nor are they simply a part of his personal network. Rather these people are bound to Dwight such that they provide significant and specific value to Dwight, albeit to greater and lesser extents. Dwight relies on these other people and information sources to accomplish his job — and for all this we see limited technological support.

Chuck the Congressional Analyst

In contrast to Dwight, Chuck is a biologist responsible for public and environmental health issues at a research service that exclusively serves the Congress of the United States. Chuck's main responsibility is to be a non-partisan expert on a number of public health issues, including the nation's blood supply and tobacco. In this case, non-partisan refers not only to a lack of political bias, but also to a lack of personal bias, that is, Chuck does not perform any of his

own research, but continuously amasses information from a variety of sources and summarizes that information as objectively as possible. As expected he uses a number of sources and, not surprisingly, relies on personal contacts.

C: "...I'm just handling more information because I'm learning more and I know more, but also because the actual sources, of that information are growing. See, when I started, you know, we relied mostly on paper and the telephone. But to that we have added in the last year e-mail and Internet so now in addition to paper, which is - which are the journals that cross my desk, the newsletters that cross my desk, the clippings that we get, the mail that comes, and in addition to the telephone messages, I now have the e-mail messages which is - and the Internet. So two more sources of information and the day hasn't grown - the number of hours in the week has not grown any more so I spend more time interfacing with these various sources of information and I spend less time reading books and lengthy documents. *I still think the telephone is the most - single most important source of information by far.*"

T. "Why? Other than because you like to talk?"

C. "Because it is specific .Because the telephone is the only way you can access exactly what it is that you want."

S: "Can you say some more about that?"

C: "Well, the - when I want to find - and I should point out that I was both as a graduate student and then as I university teacher, which I was for a couple of years before I came here - George Mason - and I continued to teach on the side to help earn money I was a freelance science journalist and I wrote magazine articles did some television . and when I wanted to know something I picked up the telephone and that's the way I still operate primarily *When I want to know something and confirm something, I still use the telephone.*

When Chuck wants to know something specific, that means he is working on a specific problem, in a specific context. He does not just pick up the phone and call anyone In fact, if he is concerned with a specific element of the nation's blood supply, e.g., the prevalence of some disease, he calls the person whom he knows personally and whom he knows understands the issue. The point is that Chuck has members of his constellation around the blood supply who are most knowledgeable given the particular context of a specific blood supply issue

However, Chuck does not limit himself to the phone as evidenced by a quick look about his office. Nevertheless, his point about the growth of information sources and the relative stability of the number of hours in a day is well taken if a bit ironic The finding and understanding of specific issues is increasingly difficult, which again pushes him to specific people and sources he knows.

C: "E-mail is getting more helpful. The problem with the Internet is that it is 99% garbage. Now given that I probably have access on here to - I don't know - 10, between 10 and 50 million pages or maybe 100 million now it might be potentially - somewhere out there - 99% of it as far as I'm concerned is probably complete crap. *The other problem with the Internet is that - the Internet is that it is unedited* The Internet is great and we use it daily The Internet is great *if you know who - if you're familiar with the source of the information* So the Internet is terrific for going into the home page of the Centers for Disease Control [CDC], the government public health agency, and it's a place that we use a

lot. Because we know about CDC, we know who they are, we know the caliber of the work they do and we know that we can rely on the information they put in their home page and so it is with a lot of other places *So if you already know something about the people - them at the other end - then that can be very useful.*

Chuck holds not only the information at the CDC Home Page as a part of his constellation, but also certain people at the CDC as related to a specific topic. Moreover, Chuck does not simply rely on information he sees, he needs to be aware of its source and the quality of the information.

Finally, and not surprisingly, much of the swapping and sharing of information comes from relationships of trust, giving as well as getting, although perhaps over an extended period of time:

C "I have had 4 or 5 phone calls in the last 3 days for information from a woman who is a staff member on a house subcommittee. She has written an oversight report .. And word is out that she is doing this, but there's plenty of people out there who would like to know what she has said and she will call me up - . . . - she called up, she wanted - it's an article from Science Magazine and she wanted some clarification So I just did some calculations saying where I get them from, where the numbers come from... Now the - that little interaction between us is a) confidential. Well, that's the most important thing about it. And b) in this case was done over a Xerox machine But it's - but it illustrates the nature of the relationship we have with the staffers that they can call us - you know, the very fact that she wants to talk about [a topic] would be of interest to other people because she - that by extension she's interested in how effective these antibody tests are and whether a . test would be better and blah, blah, blah. But she knows when she calls me up that I'm not going to, you know, divulge. This in itself is just a small piece but if you string together all the 2 dozen or so interactions Susan and I have had over the past 10 weeks, then you can begin to see what the hell she's up to - you know, as her - not foes, but the [scientific] community is kind of anxious to know what the hell she's going to say in this damn report And obviously I have a fairly good idea...."

This example shows a nice situation of reciprocity. Chuck's contacts with her offer him a chance to "begin to see what the hell she's up to" More directly, Chuck is reflecting on his role as a member of *her* constellation That is, his expertise in the blood supply (an expertise he maintains through reliance on his "blood supply constellation") and his specific role relative to congress render him particularly useful to this subcommittee staffer who's writing a report. Over time, then, the staffer and Chuck develop a relationship around this particular context -- the staffer comes to trust not only Chuck's technical knowledge, but also his discretion in these matters. It is likely that once the staffer is finished with the report, Chuck will no longer be included in the staffer's active constellations. In fact, Chuck will be relegated to "network" status. Similarly, Chuck's constellations evolve as he finds better and more efficient sources of information related to his evolving sets of issues

Like Dwight, Chuck routinely depends on a variety of people and information sources on a regular basis He has established a number of written sources for which he knows the authors, their accuracy, and their biases. More importantly,

he feels comfortable calling sources whether or not he knows them personally, but often based only on reputation and Chuck's own particular needs at that time. But finally, he has developed a set of relationships which he both feeds and which feed him in a regular and ongoing way.

Design Implications

Although our focus was on individual workers and on the ways in which they utilized computing power, we found that the most noticeable aspect of the work was not the information processing itself but the ways in which people accessed information. This is not surprising, and much can be found in sociology and descriptions of work that describe the value of interactions and trust relationships (e.g., Schrage, 1995). The significance of constellations as such, i.e. the need to be in sync, the cross-organizational relationships, and the individual-centric sets of contacts, is a set of design opportunities. For example, only Dwight can define this constellation of people and information sources; no organizational boundaries exist that include all the pieces. Equally importantly, any other person in Dwight's constellation has his or her own constellation of people and information sources that may overlap but is not defined by Dwight's constellation.

While constellations are actively maintained by each of our interviewees, the tools for doing so are person-to-person technologies like the telephone and email. Underlying databases of support are oriented toward individual networks of relationships with little or no support for flexibly recognizing daily interactions and connections. Email distribution lists recognize groups but most often from the perspective of an organizational entity, not from an individual use.

The constellation relationships and the need to be in sync require the regular awareness and informal interactions currently being discussed in CSCW technologies. But more importantly, the individual-centric aspect of a constellation offers opportunities for further CSCW development. Currently many CSCW systems such as media spaces (Bly et al, 1993) assume that the day-to-day interactions are shared primarily by a well-defined group of colleagues. Yet for any individual in a media space, the environment only supports a segment of the daily interactions. Problems in expanding systems like media spaces can, in part, be explained by constellations. For a given group of people, it is highly unlikely that their constellations will be completely overlapping. Yet efforts to expand media spaces have typically assumed a large and public collection of people. Security and privacy, however, are meaningful at the constellation level. There is at best little support for small overlapping but non-merging collections of people.

On the other hand, the cross-organizational aspect of constellations is often constrained by current technologies. Firewalls and intranets, while important for protecting a company's concerns, also contradict the reality of the work

accomplished through constellations. Technologies like the World Wide Web offer a breakdown of such constraints but, as yet, without good filters and management tools. It will be important to merge the necessities of both the Intranet and the Internet to move toward support of constellations as they already exist in working life.

Summary

In his book, *At Home in the Universe*, Stuart Kauffman discusses his ideas about self-organizing properties of biological systems. We see constellations defined from the perspective of an individual and arising, in a nearly self-organizing fashion, from an individual's particular work context. Adopting a biological metaphor, one may think of a constellation as akin to a self-organizing system of ideas. It is defined by and centered around an individual who derives the maximum value from the total set of interactions and from the total collection of ideas focused on that individual's context. The interactions arise initially, almost serendipitously, from among people who comprise teams and networks and relationships as yet undetermined. That is, constellations form around an individual with an expressed need, drawing support from other people and information sources as they are found to be valuable for so long as they continue to be valuable. Should the need diminish or the individual depart, so too would the constellation.

While the individual or hub of the constellation draws value from the assorted constellation elements, many of the people that comprise a particular constellation may not necessarily know other members of that constellation and may not even know of their own existence as a member of a constellation. In fact, the individual hub probably does not even recognize that there is such a thing as a constellation, only that there are people and resources on which he/she relies. Some elements of a constellation are more valuable than others, acquiring, organizing and eliminating information more efficiently. And more often than not, constellation elements with maximum value were external to the corporate entity to which the individual hub is a member. These characteristics are quite different from a team, where sources are shared and where members know each other and each other's value.

Given the contextual nature of the constellation, its real value is apparent only when the individual around whom the constellation revolves is in sync with the constellation elements. To be in sync means that an individual has a continuing basis for communication, ease of access, and an ongoing awareness of the status, availability, and information content from the various elements of the constellation. However, constellations are variably persistent in time, coming and going, expanding and declining as information needs present and remove opportunities to provide value.

Constellations offer an opportunity to rethink assumptions about CSCW technologies. Constellations reflect a change of perspective to consider systems based on individual-centric, cross-organizational collections of people strongly interlinked and frequently changing. Constellations suggest personal information and interaction management as indispensable to open, shared environments and appropriate incoming and outgoing pathways as essential to corporate boundary management.

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