Studying Collaborative Design to Build Design Tools

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This paper outlines the way in which studying designers at work on real problems can inform the development of new computer aided architectural design systems. From a number of studies of designers in various domains, supporting the communications of designers is re-conceptualized into one of transmitting and storing process ephemera, rather than normalizing representations. After characterizing process ephemera, an example from one of the studies is described in detail. The paper concludes with implications for the design of collaborative CAAD systems.

Keywords: collaboration, design communications, telepresence, media space, process ephemera, virtual design studio

1 Introduction

Architectural practice is fast becoming a distributed, collaborative enterprise. This trend is accelerating as computing and communications systems become increasingly ubiquitous and indistinguishable. While large design firms [1] have had networked CAD systems and even video teleconferencing rooms for some time, their day-to-day use has been hampered by poor interoperability, limited functionality, challenging operation, and/or high costs. This situation must change. As design efforts become interdisciplinary and clients become centrally involved in the process, design firms must employ more innovative technologies and practices.

Specifically, an integration of traditional co-located design practice and remote collaboration is called for. Recent research efforts are looking at this area: the Virtual Design Studio [8; 20] and its predecessors at Xerox PARC [17; 20; 10] are prime examples. These projects reach similar conclusions: that the social aspects of design are crucial; that these social factors are significantly affected by being physically distributed; and that design participants social actions are altered by the technologies that connect remote locations. Furthermore, empirical studies of design [9; 12; 7] have demonstrated that design is a social activity as much as it is an individual practice. One small step further-supporting the social communications is as important as supporting communications about the design problem. It should come as no surprise that developing systems for collaborative design is different in both method and form from working on systems for individual designers.

Our research program at PARC is two-pronged: to carry out studies of actual design practice and to develop new technologies to support design activity. The studies have ranged over a number of disciplines and always employ designers with motivated projects involving real clients; we have looked at the design and construction of a small house addition, the conceptual design phase of office space, the design of a fix to a subsystem in a copier, the modification of the interface to office system software, and the

development of an environmentally friendly refrigerant vessel. Since our methods focus on the social relations in these work settings, we have applied them to some parallel studies of office work as well--most notably, our own distributed research lab [6] here at Xerox Palo Alto Research Center (PARC) and most recently, the ways in which ideas for patents are captured, evaluated, and processed [14]. Often, the studies are of situations using some of our design support technology: for example, using video as a shared work surface between two user interface designers.

One interesting outcome of this research has been a redefinition of the general notion of representation in design. The search for a common unifying representation has been a holy grail in design studies and in CAAD system development for many years. Detailed studies of actual design practice, particularly as carried out in settings where parties are at a distance from one another, leads to another formulation of the problem and new framework for developing all kinds of CAAD systems. We have noticed that in all the settings we have observed, designers use different kinds of representations in widely varying media at different times. This variety is a crucial resource to the designers (more on that later)--it needs to be celebrated, and what is more important, it re-conceptualizes the role of computer-aided design.

2 Process ephemera

As projects progress, the objects that are actively employed by designers in the process of design change. At one moment, it might be sketches and a rough model, at another, it might be product samples and presentation drawings. While most work is done on the drafting board, some of the material is around the room: drawings are piled on desks and in flat files, sketches and photos may be tacked to walls, and copies of specifications from old projects often lie piled within easy reach. We call these artifacts process ephemera.

The materials are ephemeral in that they are useful in the moment. The classic example is the cocktail napkin sketch. One often-missed detail of this example is the extent to which the hasty marks on that flimsy paper are only a small fragment of a larger whole. The context of that drawing--the place where the sketch was made, the conversation around it, the gestures over it, the facial expressions about it--are where the real value lies. In fact, the sketch is often meaningless without the context [18]. The materials are also ephemeral in their relations to the project and to other representations in it: a couple of days might be spent putting together a study model, referring to sketches and early plan layouts. When complete, it might be looked at intensely, then tacked up on the wall along with photos cut out of magazines and photographs of the site. At a presentation to the client, someone might grab it again to explain some point that a drawing doesn't effectively convey.

We will explain the salient aspects of process ephemera using a few observations from our various cases and then follow it with a comprehensive example from one of our more extended design studies. Following that, we will show how this reconceptualization should pivotally influence computer aided design systems.

2.1 The elements of ephemera

We think of anything that is a communicative resource in design as process ephemera. Both sign and signal are communicative resources; a sign is content (like a picture of the site or a manufacturer's brochure) and a signal is a meaning that is readable although not necessarily intentional (a telephone left off the hook at a vacant desk strewn with notes can be read as "occupied--the person who works here is off looking for something to continue a conversation").

2.1.1 Many forms/many media

It is obvious that the communicative material of architectural design is found in many forms: notes, sketches on tracing paper, photos, slides, textual specifications on paper and in CD-ROMs, models made of foamcore and models made on CAAD systems, recordings on answering machines, and even e-mail. As projects progress, the list of things changes and so therefore does the number of kinds of media.

Of course, the items themselves often also change. Drawings get made, specifications are written, etc. Not only do they change in themselves, they change in their relation to one another (for example, as specifications and drawings develop, they

reinforce one another). These objects are often placed in juxtaposition with one another-and thus one media is placed in relation to another (e.g., sketches on paper are held up next to the CAD station).

2.1.2 Both foreground and background

In what sense is something actively employed in design? While many current things are found on the designers desk, things are also on adjacent desks, pinned to the walls, and/or carefully organized on library shelves. This material is often still part of the active suite of resources that designers employ, even if they are not focusing on them. Beyond glancing at them to be reminded of previous detailed examination, designers use the photos tacked-up around the walls to keep together the context and direction of the project.

This interplay between a central focus and periphery is common in the workplace; recent anthropological studies of even unskilled" workers reveal how people monitor and capitalize on the periphery to smooth the workings of purposeful activity [15].

Physical space has great utility: in the architectural studio, even people across the room holding a (possibly intrusive) conversation becomes a kind of resource that is available to designers (fleeting conversation is probably the most ephemeral of all ephemera).

In the daily use between Palo Alto and Portland of our own collaborative environment, the common spaces outside of colleagues offices were routinely linked by compressed video and speaker phone. Any activity in one location was present in the other and the users at each location acted with that in mind. A conversation in one would be overheard and joined by people at the other. In this way peripheral activity (the overheard public conversation) would become central.

2.1.3 Comes and goes

While some material is present (as central focus or in the periphery), some is simply absent, stored away, or even forgotten. That much of this material is brought into play in a design project at a specific moment--the current "hot" notion--makes it hard to file away and even harder to find again. Most often, office custom or personal whim decides what gets saved and where, so that human memory and/or exhaustive search is the only way to find it again. In all of our studies, there are critical moments when someone will as around trying to locate some item that was stored away.

In the study we did of a fix to a mechanical engineering subsystem, a great deal of the management of the project was the management of the paper. Reports and memos would be distributed and would shape the design discussion for the next few days. The introduction of a new report would typically supplant not just the explicit content but would alter the language of subsequent discussion.

2.1.4 Conversation

What ties all this together? While the knee-jerk answer might be, the final design', it is not, since often ideas are tried only to be discarded. [2] But if not the final design, then what? Again, turning to the study of design practice, it is the conversation of designers. As the process unfolds, these objects are employed in them. As we will see in reviewing some studies of design, the use of this material is dictated by and managed through the on-going conversation.

2.1.5 Accretion of understanding versus more knowledge

The process of working together in design appears to be one of developing a shared understanding of a problem and the final artifact [12]. If collaborative design is largely an accretion of understanding, why are there more and more drawings, specifications, etc. that come into the process with more and more bits of interrelated detail that must be reconciled and related? If there is much that is tossed or forgotten, or will go unused, what is going on here? The material of design is as much "assembled" as it is written or drawn. Assembly is a an expression of the shared understanding as well as a vehicle to develop the understanding.

Just as this is not about building ever more detailed representations (although many choose to work this way), it is also not the development of an ever increasing spiral of knowledge. Another way to say this is that a rich assemblage of ephemera is not in itself

a representation of knowledge, but a tool through which the collective understanding is expressed and discussed.

3 A comprehensive example

To explore the aspects of process ephemera, let us turn to a study we conducted of industrial designers at work in a distributed environment. We arranged for some members of a product design team from David Kelley Designs (DKD", now "IDEO') of Palo Alto to work remotely from one another using a variety of electronic tools.

Unlike student projects such as the Virtual Design Studio, this project had experienced designers with deep knowledge to fall back on and a real client with whom to negotiate both the design brief and the design solution. Furthermore, the designers had longstanding working relations with one another, so they already had some sense of how to hold a conversation with each other, areas others were expert in and areas they were weak in, private language unique to DKD, the work method of DKD, and the work habits of others.

We created a virtual design studio (or "media space" [3]) for DKD with one office at their regular facility and another at Xerox PARC, ten miles away. Because of the interaction between systems and social effects, and our own resource limitations, we choose to address the social and pragmatic design needs with communications and computational technologies that were familiar--or at least, were approachable by the user in familiar ways. The two rooms were linked by an audio teleconferencing speaker phone that was always on, video teleconferencing using 56 Kb compressed video (also always on) and multiple cameras, FA)(, a shared file system for the CAD system, and a shared drawing system called 'Commune'. Unlike architectural studios, their facility is a warren of interconnected spaces most of which are two-person offices. People move freely through them, but they are visually and acoustically separate from all but the closest neighbor.

Figures 1 through 6 illustrate a typical sequence of encounter across the link. Notice the items in the environment and how the cameras tend to alter the notions of center and periphery, absence and presence, and the role of conversation.

Since this project was studying the interaction between social setting, design technology, and physical distribution, both offices were videotaped for the duration of the project. Prior to the project, the work day of one of the designers who re-located to PARC was videotaped. In addition, open-ended interviews were held with most DKD personnel who interacted across the link. The tapes were subsequently reviewed for types and duration of observed activity, conversation, coordination of activity between sites, close coordination of interaction, types of media used, and interaction between media.

In the following, well try to highlight how sign, signal, multiple forms, multiple media, foreground /background, center/periphery, presence/absence, conversation, and an accretion of understanding unfold in this setting. By paying attention to how these aspects of process ephemera arise and were handled by designers in this study, it is possible to get some understanding of how to address it in a CAAD system.

3.1 Working together, apart

In order to design a mechanism, our subjects would show parts to one another. Using the 56 Kb video link, they simultaneously reviewed the parts, guiding each other through the salient details and directing re-positioning of the others' cameras. Figure 7 shows the central ephemera of this setting: a notebook with prepared sketches in it, parts of similar mechanisms, pens, and a small plastic ruler.

They would sit in relation to one another as they would in physical space--but they were not both able to use this new arrangement as they would a real table. This resulted in them having unparallel experiences. Gestures and objects in each engineers space never crossed into the other--only their images. They showed up in different relation since the placement of cameras and monitors is a compromise between the separate physicality of the apparatus and the convenience and preferences of each designer. Although the physical relationship of people was similar, the space was not shared by both parties, and were at times invisible to the other. There was an ambiguous relation between the image on the monitor, the objects under discussion, and the continuity of the electronically created office. It was two places at once, one that created a single

environment by linking two separate physical environments and one that contained the image of the other.

In addition to the central ephemera, there were also peripheral ones: on the desks at each location were familiar objects--tools of their design practice (like spec sheets, calculators, and drawing implements) and additional sample parts and prototypes. Some were duplicated in both locations, but none were in exactly the same spot. They would often be brought into play by designers.

Defining edges to each work space were shelves (fixed to the walls at PARC) and rolling carts at the DKD office. These were visible background frames for more ephemera. The ephemera on them were more isolated in the framed image of the camera-and therefore more central to the remote party, but more present--but more peripheral--to the local party.

3.2 The virtual office meets the physical office

The designers colleagues reported that they would "go to Dan's office to find Dan. They frequently walked into his office and asked, "Dan, are you there?", before they could see his image on a video monitor or themselves be seen by the camera. In other words, they acted as though he was available in the same space, or as if the place--Dan's office-was a combination of the two locations and the technology that connected them. The electronic place existed as an adjunct to the physical space that gave it its name.

At other times they would look in, see if he was visible on the monitor, verify that he was interruptable (e.g., not on the phone), before striking up a conversation. In this case, his image was a signal to others of his state--something that is lost in a regular phone call, but acutely present in the architectural design studio.

The patterns of the surrounding physical environment were continuous across the electronic link in both directions and were present in the virtual acoustic and virtual visual spaces, as well. And once someone yelled out for another person in the group, only to be answered by a colleague at the geographically remote site saying that "Fred isn't here." The space not only extended across the two sites but beyond the visual screen to the audio waves..

3.3 Human mediation

Ishii, in developing user interfaces for collaborative systems, suggests that a key design principal be "seamlessness" - that is, the ways in which one can move from one kind of use to another [11]. One familiar collaborative activity is drawing together, or more accurately, drawing and pointing at elements of the drawing while holding a conversation [19].

Two approaches to drawing together are contrasted: there was both user positionable video teleconferencing and a separate shared drawing system called Commune". While Commune [4] was the result of much careful research on collaborative activity, the users created their own shared work surface out of the teleconferencing equipment. The users were able to use "Commune" without difficulty in trial demonstrations, but it was never turned to during conversations. Instead, when there was a need to share a drawing or a sketch, an ad hoc shared surface was created by pointing one of the video conferencing cameras at the video conferencing monitor. [5] This permitted someone to point with their finger at the image on the screen from the other location.

This example highlights the way in which human mediation not only handled the disjoint activity, but also negotiated the transition of central focus and periphery moving from one to another.

Where both were aimed at including the subject matter of the design into conversations between the two place, the ad hoc system had the following advantages:

(a) It better communicated a sense of presence: since the video image allowed users to the other see people's faces, see when there was activity and what that activity was, and it showed hands making the gesture more human.

(b) It was a more natural conversation: since dyxsis was more robustly handled, turn taking, attention could be more readily re-directed, and secondary signaling (like giving a 'thumbs up" or expressing the need to interrupt) was easier and clearer. Furthermore, two-handed (or two-fingered) gestures of size, location, and animation were possible.

(c) Small objects could be talked about as well as drawings.

(d) Because of this, learning to communicate was easier. The special language that arises in communities was seamlessly part of the space of the transmitted images.

And, these facilities were seamlessly handled.

4 A framework for designing collaborative design systems

What are the requirements for technology to support this framework? What does this say about the design of systems for remote design collaboration? Some of the salient aspects of a distributed social realm are the ways in which acquainting new members of design teams with each other takes place, learning to communicate between designers with different "cultures" occurs, designers maintain a presence to others on a project, designers see as others see, and they hold "normal conversations". While there are others, these encompass most of the difficulties encountered by designers and the shortcomings of looking at distributed design as merely one of getting everyone on the same shared CAAD system.

The primary aspect is that any of the ephemera (but not necessarily all) should be meaningfully shareable. By now, the reader will be really uncomfortable since we are suggesting that the primary requirement is to be in shared space with all the properties of a design studio. Thoughtful readers will be (justifiably) even more uncomfortable since we have not distinguished between tools and representations in our definition of ephemera. Yes, just because this a new conceptualization, it does not mean that it is simpler one to implement.

4.1 Heterogeneous representations

There is no substitute for being present with one another. But electronic technology coupled with high bandwidth communications has great potential to convey the appearance of place, artifacts, people, and activities. Many items are more conducive to shared electronic space (CADD, imaging, etc.) than others. Transmitting content in a different media than its original transforms the content; transmitting content without its context transforms its meaning and transforms the context into which it is re-displayed; and transmitting content and context without the setting in which its sender experiences it transforms the new setting.

One strategy is to put everything into electronic space so that it is equally available to all and in a uniform medium. This is unrealistic for the foreseeable future since it would require that designers be disciplined enough to never sketch on paper, build physical models, or talk with people in person--to say nothing of the expense of transmitting all conversations, storing all sketches and notes, and the equipment necessary to display it all

An alternate strategy is to treat this problem as an opportunity: designers at different sites work with whatever media and material is at hand, but transmit as much of it as possible. The electronic space is of two sorts, a shared work space (e.g., a shared CAAD system) and a means to get material present at disjoint sites (a FAX system for material to be pinned up around the studios). The transmitted material is used to reduce the rate of decay of the rich space that is shared. The electronic space is not a substitute for physical adjacency, but it does extend the reach of the remote collaborators beyond their displays to their respective studios.

Besides supporting a wide range of media, the media needs to be robust enough to support the subtle signals that some media afford. A key example of this is the ability to tell what parts of a sketch are about ideas that are not worked out. While it is possible to explicitly tag items (i.e., to sign them) as not worked out, this is at variance with the development of a shared understanding.

4.2 Support both center and periphery of work space

As we have shown, both material that is the central focus of work and material on the periphery are employed in design. There are a number of consequences of this observation:

(a) Display. Not everything will fit on one display; some display area needs to be at the periphery.

(b) Network. Bandwidth requirements vary by object. A shared work surface requires medium resolution and low latency; a pin-up high resolution but relatively low bandwidth.

(c) Synchrony. Because the periphery is an active resource, it must have common elements at each site. Imagine using printed images pinned up at each site in distributed design-need to have some sense of what others have available.

The requirement therefore is to support heterogeneity in pick-up, storage, transmission, and display. There needs to be seamless connection between displays that are the focus of work and those that are on the periphery.

4.3 Conversation

The system must support fluid talk between parties. Fluid talk in design consists of all parties being able to:

(a) make gestures with their hands over, towards, and about the material;
(b) sketch;
(c) direct the attention of others;.
(d) gain the floor; and
(e) hold side conversations.

Critical to the successful implementation of such systems is synchrony between the visual images and the conversation. Delays caused by video compression, network gateways, computer re-displays, competing processes, or signals traveling different paths readily disrupt conversation and distort meaning.

4.4 Human mediation of storage

Distributed design collaboration using electronic media does not obviate problems of physical storage of process ephemera. Since material readily comes, goes, and returns, the ability to record, locate, and playback is vital. In all of our studies, there are critical moments when someone will ask around trying to locate some item that was stored away-even items stored on shared file systems. The design of remote collaboration design system should support this; one approach is to support casual human accessibility as part of the design environment.

4.5 Accretion of understanding

The development of systems that support the other aspects of process ephemera will by their nature support the development of shared understanding among design collaborators. The display of the accretion of material at any one moment in the design process is a reflection of the understanding. This is best accomplished by. using representations of process that are accurate histories of the design activity. Those histories are useful to the extent that designers can re-experience the process of design. This is useful for bringing in new members of projects or people who have been absent. The technology would try to re-create the ephemera as it was used at particular phases of work or even at specific moments in time (we are currently exploring just such a system [14]).

5 Conclusion

We have seen how observing designers at work--and particularly in remote collaboration situations--can suggest new approaches to supporting design. In this example, we began with the idea of process ephemera and through that idea uncovered some interesting system elements: seamlessness, heterogeneity of media, human mediation, the importance of physicality, and the centrality of conversation.

Collaborative CAAD should not represent the abstract qualities of social interaction, but the provide a platform to support social interaction. Designers in this study were able to act towards each other and their work in ways that were at once familiar and grounded in real-world experience, and ways that are new and aphysical.

6 Endnotes

[1] For example, in the early 1980s, Skidmore, Owings & Merrill used networks of DEC VAX computers throughout their North American offices; since the systems were centralized time-sharing environments they could provide operational backup and permitted engineering design and analysis to be carried out in one office while architectural design was done in another. They also had teleconferencing rooms in their New York and

Chicago offices; the expensive telecommunications costs limited system use to management functions and occasional client meetings.

[2] This is even more complicated since there are many ideas in design that are raised as reference, either as analogy or as inspiration (such as, "Like Wright did at Fallingwater...).

[3] For a discussion of "Media Space' projects that illustrate substituting electronic connection for physical space see [16; 6].

[4] Commune is a deceptively simple system: like many "mark-up" facilities in commercial CAD systems, it has a dedicated work surface with a stylus permitting marks made at either location to be seen by both users. Intended for use with an audio conferencing system, it not only shows the marks but also the remote cursor position so that one can make gestures with the stylus to disambiguate words like "that one" [13].

[5] This technology reconstructs "VideoDraw", an analog shared drawing system that was a precursor to 'Commune" [19].

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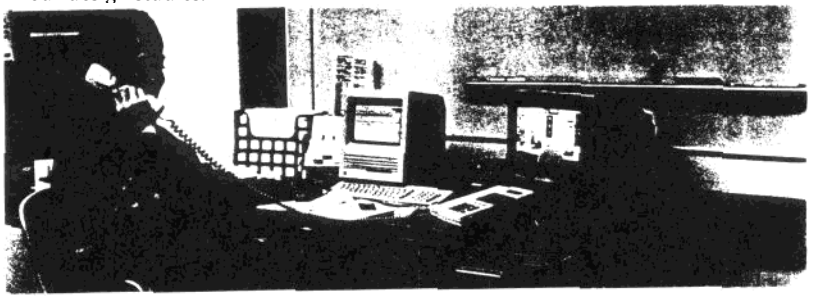

Figure 1 - Interaction Sequence. The designer, on the phone, not using the link. (Note that the chair in the monitor is vacant.) Although there is an open connection with the speakerphone, he is operating within the confines of this physical space.

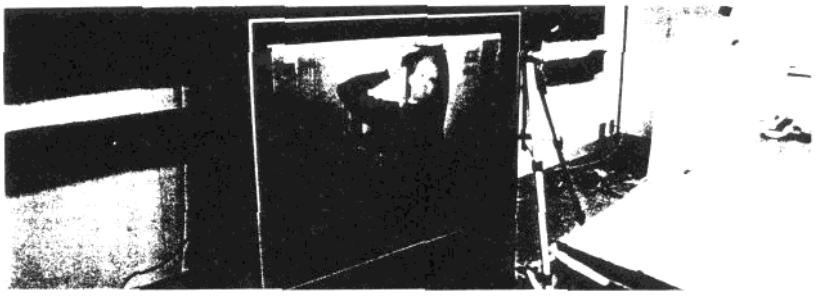

Figure 2 - Interaction Sequence. Someone arrives at the office at DKD, sees and hears the designer (sitting across the table, to the right of the photo) talking on the phone. He waits for him to complete his call.

Figure 3 - Interaction Sequence. Seeing the visitor in the small monitor on his desk, the designer turns towards the large monitor (and less directly, towards the camera and speakerphone).

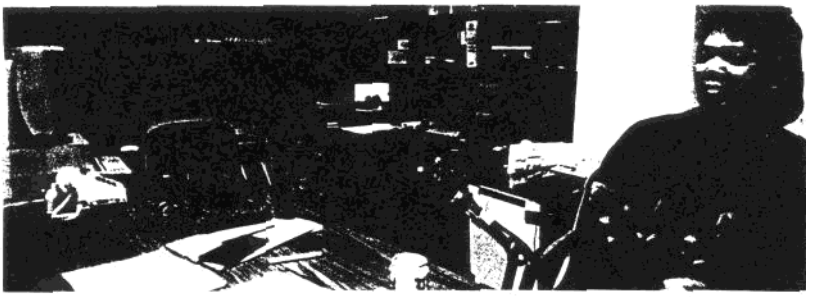

Figure 4 - Interaction Sequence. The conversation begins.

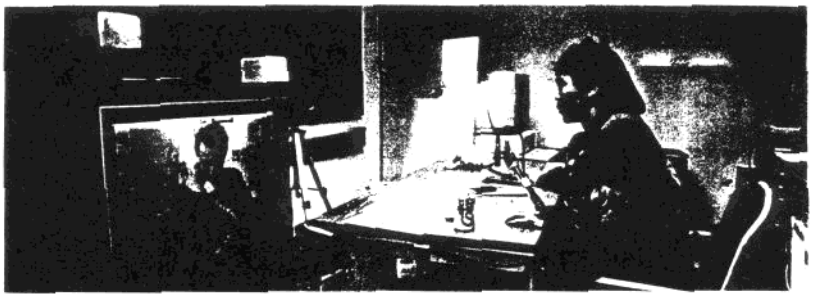

Figure 5 - Interaction Sequence. As the conversation proceeds, the visitor substitutes the handset for the speakerphone so as not to intrude on the other occupants of the open office at DKD. The designer carries out the discussion with the visitor as though in his office. Note the outgoing image shown on the small monitor is framed to show mostly the designer's head and shoulders and very little of the work surfaces.

Figure 6 - Interaction Sequence. Showing the visitor some of his sketches, the designer positions a sheet of paper under the small camera and he looks for visual signals of recognition and acknowledgment from his visitor. The session will soon conclude with the visitor saying good-bye and standing up, and the designer turning his back to the camera, returning to the work on his desk.

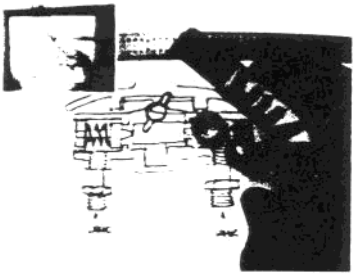

Figure 7 - Communicative Resources (video stillframe). The large image is of some full size sketches from a notebook, some parts that would be in the mechanism, a small scale, a pen and the designers hand animating its performance. The inset is of the remote image; the camera is pointed at the monitor so that the remote collaborator can interpose his hand for pointing and animating.