Stepping into Cooperative Buildings

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Abstract.

If we are stepping out of windows, what are we stepping into? We suggest it is into cooperative buildings. For the foreseeable future, at least, we can identify two major characteristics of the cooperative building. The spaces of the building will be augmented in various ways, providing an ambient environment that bridges spatial discontinuities in workgroups and provides a continuous window into the state of the virtual world. Secondly, the ways in which the spaces themselves are used will evolve to be more congruent with the fluid, dynamic and distributed nature of the work taking place in the building. These two characteristics are deeply interconnected. This evolution need not happen entirely in the physical world; the essence of a cooperative building will become the way in which it mixes both physical and virtual affordances to support the work-a-day activities of its inhabitants.

1. Introduction

There is no doubt whatever about the influence of architecture and structure upon human character and action. We make our buildings and afterwards they make us. They regulate the course of our lives [Winston Churchill, cited in 1].

Buildings achieve the outcomes attributed to Churchill because they are primarily social vessels — the structure of buildings creates a kind of sociological structure that shapes and influences the ways in which we work, socialize, and interact. The shift to cooperative buildings requires several mutually interdependent re-conceptualisations of what we mean by building , work and interaction : First, a shift to organ izational thinking and structure that emphasizes a knowledge-based, flexible, distributed, mobile and dynamic enterprise; second, a shift to flexible, team-oriented spaces within buildings; and last, a shift to the use of information and telecommunications technology as a mechanism for overcoming the effects of physical dislocation. These changes will profoundly affect the ways in which groups and individuals work, and the ways in which they conceive of the buildings that house them.

These shifts characterize the changes required as we step out of windows. The question we ask is: if we step out of windows, then what are we stepping into? To a large extent we believe that cooperative buildings are the answer to this question.

In this paper we explore some aspects of these shifts, focusing on the evolution of new forms of office space, and ways in which information and telecommunications technology can be used to extend or simulate them. In particular, we focus on *augmentation,* a technique whereby a user s workspace is augmented by various kinds of information, emanating from both the virtual and the physical worlds, which enable her to be more aware of the activities of other group members, and share and coordinate work activities more effectively.

We begin (Section 2) with a general discussion of new forms of office space. This leads into a description of the information technologies that support and mediate interaction (Section 3) and technologies for augmentation (Section 4). We then overview three case studies of distributed and dynamic organizations (Section 4) which used a mixture of physical and virtual affordances with varying degrees of success. Finally, (Section 6) we discuss synergies and future directions.

Table 1 Contrasting traditional and new offices [2]

	Traditional Office	New ways of working
Patterns of Work	Routine processes, individual tasks, isolated work.	Creative knowledge work, groups, teams, projects, interactive work.
Patterns of occupancy of space over time	Central office locations in which staff are assumed to occupy individual workstations on a full-time basis. One desk per person; provides hierarchy; occupied below 70% of the available time.	Distributed set of work locations; nomadic, mobile, office or home. Linked by communications networks, autonomous individuals work in project teams. Daily timetable is extended and irregular. Multifunctional work spaces are occupied as needed, occupied close to capacity.
Type of space layout, use of space and buildings	Hierarchy of space and furniture related to status. Individual allocation of space predominates over group spaces.	Multiple shared group work and individual task based settings. Setting, layout and furniture of the office geared to work process and tasks.
Use of IT	Technology used for routine data processing, workstations in fixed positions.	Focus on mobility of IT equipment used in a variety of settings. Technology used to support creative knowledge work, both individual and group.

2. The New Office

Architect Francis Duffy has documented many contemporary office designs as well as the co-evolution of office work processes, practices and workplace designs [2], and predicts a shift to a more fluid, distributed and dynamic work environment. Workgroups will be spread around (within or across buildings), workers will be increasingly mobile or nomadic, and so on. As part of this evolution, the office itself is finally undergoing a long overdue re-conceptualisation. Table 1 captures the evolution in office space and ways of working.

From this summary a variety of physical layouts are implied. No one stereotype emerges, but rather a flexible mix of workspaces, where varying degrees of autonomy and interaction are available, known as hives, cells, dens and clubs. Table 2 summarises the salient features of all four types of office space.

Duffy argues that the relative proportion of the four types of office space will change as demanding, team-based, high-interaction cooperative activities become commonplace. Whereas at present hives and cells dominate, over the next decade dens (and possibly clubs), which support group processes, will become increasingly common. In the context of cooperative buildings, it is our contention that this evolution need not happen entirely in the physical world; the essence of a cooperative building will become the way in which it mixes physical and virtual affordances to make the building work by supporting the workaday activities of its inhabitants.

3. The New Interactions

In parallel with Duffy s work on the New Office, information technology has been evolving to support more sophisticated interaction mediated by computing or telecommunications networks, particularly through the field of computer-supported cooperative work (CSCW). Such technologies are interesting in the context of cooperative buildings because they suggest ways of creating virtual spaces that can aid in the provision of Duffy s four office types. Notable technologies include:

Video and Audio Conferencing: Video and audio conferencing systems extend a traditional computer to provide video and audio I/O, and then link computers together to share video and sound. Generally used for relatively short-duration conferences, and provide a way of simulating a face-to-face meeting from a distance. The addition of *application sharing* allows limited sharing of tools and applications in the meeting.

Media Spaces: A media space [see 3] attempts to bridge multiple physical spaces with a collection of video and audio affordances. One way to think of a media space is as a multi-way, continually operating video and audio conference linking multiple physical spaces (such as offices, meeting or recreational areas). While a media space uses the same underlying technologies as a video/audio conference, its intention is radically different: rather than simulating a distributed meeting room, its explicit purpose is to warp space, turning cell or hive-like offices or meeting areas into more den or club-like areas.

Collaborative Virtual Environments: These environments [see 4] simulate physical space in the computer, with an avatar representing the user in virtual space. This paradigm allows users in different physical locations to come together in virtual space for a meeting. Since virtual space is infinitely malleable, the spaces can be configured into any of Duffy s configurations, but it would be more common to create communal areas such as performance arenas, dens or clubs.

Table 2 New types of office space [2]

	Hive	Cell	Den	Club
Patterns of Work	Work broken down into smallest component and staff given little discretion.	High-level work carried out by talented independent individuals.	Project or other group work needing a changing mix of interdependent skills.	High-level work carried out by talented independent individuals who need to work collaboratively; work process changes.
Patterns of occupancy of space over time	Conventional 9-5. Low interaction.	Increasingly ragged and variable, extended working day. Some possibility for sharing of space.	Conventional 9-5, becoming varied as sub-group activities vary. Opportunity for sharing space.	Complex and dependant on what needs to be done, individual arrangements, high-occupancy pattern over project periods, else intermittent occupancy and shared task settings.
Type of space layout, use of space and buildings	Open, minimal partitions. Imposed space standards.	Cellular enclosed offices or individually used workstations with high partitions.	Groups spaces or group rooms. Complex and continuous spaces incorporating meeting spaces and work spaces.	Diverse, complex and manipulable range of settings based on variety of tasks.
Use of IT	Simple networked PCs	Variety of individual PCs on networks.	PCs and shared specialised group equipment.	Variety of individual PCs on networks and use of portables.

Shared Repositories: A shared repository manages a collection of artefacts or documents for use by a group. The simplest shared repositories are shared file systems, but more sophisticated examples support document management and versioning [5]. Shared repositories are important to virtual office spaces because one of the primary reasons for creating any form of office is to provide a shell within which artefacts (eg accounts, plans, reports, etc) are manipulated.

Awareness Management: The physical world is richly endowed with cues that we use to keep aware of the activities of others nearby, and which facilitate the continuous, contingent rearrangement of our workaday activities. Examples include doors opening and closing, people moving about, objects being dropped or moved, overheard conversations, mail delivery, and so on. Without these subtle cues, workplace practices soon break down [6, 7]; and these cues are largely based on co-location, being in the same aural space, being in view of a colleague, etc. Awareness systems [8-11] play the dual role of keeping people who are distant from one another aware of each other s activities, and make visible actions in the virtual world, which would otherwise be invisible. They are thus fundamental to any virtual office support. We d evelop this theme in Section 4.

Shared Context Management: Shared context management systems such as Orbit [12] or TeamRooms [13] combine together the features described above to create virtual shared offices (called zones in Orbit or rooms in TeamRooms) in which users can interact, work together, share documents, chat, and do the work of an office. These environments can be configured to support interaction among workgroup members regardless of location, and can thus be use to create a mix of virtual cell, den and club-type spaces.

Taken together, these technologies potentially allow the design and construction of Duffy-style interaction environments in the virtual world. Of course, the virtual world is too impoverished to be a complete replacement for physical office buildings — interfaces are too limited, interaction is too hard and insufficiently fluid, information is too difficult to share, and so forth.

Thus, while Duffy takes a purely space-oriented view of what comprises the new office , in reality a *mixture* of both physical and virtual structures is needed. This mixture will add a new dimension of flexibility to the office. It will allow for support of virtual teams (something Duffy doesn t seriously address). Perhaps, more importantly, it will facilitate the construction of den and club-like facilities *through the virtual* — facilities that will allow the existing stock of hive and cell-like spaces to be flexibly and cheaply reused, while still effectively supporting the work practices that will drive the new office paradigm. Although all the technologies mentioned above will play a significant role in this new office paradigm, it is *augmentation* that will be the critical element, making it pos-

sible to bridge seamlessly and relatively continuously between physical and virtual spaces.

4. Augmentation

Cues and hints will remain important for work in the cooperative building, and two significant problems will arise. First, the spatial distribution of people and things will no longer be a reasonable determinant of where their related cues need to go (for example Bill showing up at work might be interesting for Bob, who is now in a different building). And second, new families of cues will arise (and indeed already do arise) from the virtual world, as more work activities take place through or in computer networks.

In this section we look at several ways of augmenting the workaday world to keep these cues (both physical and virtual) in view and to provide a greater variety of spaces. The basic idea is as follows: Because users are physically distributed, but need to work together closely, a variety of awareness and notification mechanisms are used to help them keep their work contingently synchronised. That is, such mechanisms can augment distributed spaces to provide different types of other spaces that afford relatively continual connections. In a similar way, they can also be used to augment the existing stock of office cells with some of the affordances of co-located spaces such as hives, dens and clubs.

We have therefore been investigating the design and use of an *augmentation infrastructure*. The core of our infrastructure is an *event notification service* (called Elvin) [9, 14] that takes responsibility for ensuring that when an interesting event occurs, all parties that need to know about the event are notified appropriately. This service is complemented with appropriate event producers and consumers. Producers are tools (or add-ons to tools) that emit notifications when appropriate events occur, for example when Bill arrives at work, or when Bob receives a new email message. Consumers are tools which take this event information and make it visible to users, for example by popping up a dialogue box, morphing an icon, scrolling a message across a marquee, sending a message to a pager, or emitting an appropriate sound. Taken together, these various event notifications help to keep one informed of activities that are taking place remotely.

Elvin employs a content-based publish-and-subscribe paradigm in which consumers subscribe to event patterns, and then receive all events matching that pattern. This decoupling of producers and consumers results in highly flexible and evolvable event-based communication.

A number of different interfaces have been constructed which allow users to see , and sometimes produce, notifications. The most popular of these is Tickertape [15], a highly tailorable tool built on top of Elvin. It can function as an event consumer that displays event information that the user subscribes to. It can also function as a means of event production in that the interface can be used to construct messages that are then sent out as notifications.

The Tickertape interface, as shown in Figure 1, consists of a single rectangular window, showing small, colour-coded, active messages and graphics that scroll from right to left. Each message corresponds to an Elvin notification that has been received by the Ticker application. For example, the left-most message in the figure is from user arnold , has been sent to the group b&d , and has the text so my monitor works . The ticker is designed to take up minimal space — the active area is a single line, and borders, etc can be removed to make the ticker fade into the background . Most users position their ticker(s) on the edges of their screens, where they provide a simple kind of peripheral access to the information that scrolls by. Ticker users subscribe to messages at two levels: they indicate the groups they are interested in, where group is an attribute contained in the content of all messages to which ticker can subscribe, and they indicate some filters over the contents of messages which have the appropriate group attribute values. Events with MIME attachments are coded with special graphics. Individual notifications have a user-defined, group-specific lifetime over which their appearance fades, thus providing an indication of how timely the information is. Users can also choose to delete or save a scrolling message by clicking on the message itself. Tickertape messages come from a variety of sources, ranging from human-based (chat-type applications) to various kinds of computer-generated notifications.

One of the most popular uses for Tickertape is as a lightweight channel-based semi-synchronous chat tool. Users can define new groups by convention with their peers and then send and receive messages in those groups. Chat groups are used extensively within our organisation by both technical and non-technical staff, especially as people are distributed across different offices on different floors and were, for a time, in different buildings. Interactions over these bi-directional groups tend to be spontaneous, short, in-formal, often irreverent, and bursty , similar in nature to face-to-face conversation, and it is in this sense that they augment the workaday environment. In some ways this simulates one of the simple affordances of a hive, i.e., the ability for someone to easily turn around to a neighbour and ask a question. They also incorporate the synchronicity and immediacy of the telephone with the asynchronous nature of email and are especially suited for temporally relevant information, such as there are cakes in the kitchen .

Figure 1 The Tickertape interface showing exemplary scrolling messages

Very quickly, Tickertape has become embedded into the working environment of the organisation as yet another means for communication and interaction along with the telephone, email, face-to-face discussions, and porthole video images. Each of these has particular uses for which they excel and Tickertape has found its niche amongst them. It is not uncommon to see a discussion over Tickertape that ends with a comment such as uh oh, see email or wait a minute I m coming down when the content of the discussion becomes more detailed than can be usefully handled in short chat messages.

Another significant use of Elvin and the Tickertape has been for uni-directional events where pre-existing external event streams are instrumented to produce Tickertape notifications. This supports awareness through notification, providing content-based information filtering. Event streams in regular use include postings to Usenet news groups, commercial news sources on the World Wide Web (WWW), personal email notifications, a schedule system, and instrumentations of various file systems, web repositories and document repositories. Generator code is written to translate the event source into an Elvin notification, so that in each case users are kept aware of the changing state of the appropriate slice of the virtual world.

It is important that the various sources of augmentation (chat messages from users, cricket scores, notifications about changes to a shared document repository, etc) are all melded together — the resulting juxtapositions create an ambient environment which continually sparks new interaction. [14] has a significantly more detailed discussion of Elvin, the Tickertape and their augmentation capabilities and impact.

5. Application: Case Studies

In this section we briefly outline — through a series of vignettes — a scenario in which the group makes use of the affordances provided by augmented space in cooperative buildings. A mixture of physical and virtual spaces are used to support a work team. Of particular importance is the way that all aspects must work together: serendipitous and informal interactions must be easy and continuous; team members must be continually aware of one another, and capable of contingently rearranging their work activities as needed; the spatial layout of offices and the kinds of work they afford (e.g., cells affording private, contemplative work vs. dens affording more vigorous team or project work) must be appropriate to supporting the right level of noise and quiet, formal and informal interaction, and provide adequately configured space; meeting spaces must be available; the information technology must give the right people access to the right information and bridge distance as needed; and so on.

To illustrate the use of these concepts we run through a day-in-the-life scenario of the group of developers working on VSAD, a complex command-and-control infrastructure under development for one of our sponsors. While we ve set the scenario some years in the future, and taken some liberties with the technologies that would be used, the scenario is based on real-life experience with current versions of the Elvin-based technologies we describe.

Setting the scene: VSAD requires integration of several different products built by different parts of our organization located at different company locations: the Elvin event service and StarBurst collaboration framework (Brisbane), the Gale workflow engine (Gold Coast) and Viable component management infrastructure (Melbourne). To accomplish the task in the time available, a VSAD tiger team has been pulled together with representatives of each of the groups, making a total team that can range in size from a core of 4 programmers to a larger group of 15 or so, depending on the task being undertaken.

Fortunately we have recently installed a range of new technologies for spatial augmentation which should make the task we re tackling a lot more feasible.

Early morning: Bill arrives at work, irritated. Last night he had left early to pick up his kids from sport, with a critical portion of the integration incomplete. He s not at all happy about problems that have been uncovered in the Viable component glue libraries; it turns out that Viable makes some assumptions about interrupts that are incompatible with Elvin s event callback structures. He d written out a detailed description of the problem, complete with annotations showing the ways in which it shows up, and left them on the group s shared noticeboard, and he wonders if the Viable group down in Melbourne has been dealing with them.

As he crosses the threshold a chirpy voice pipes into his ear: Good morning Bill. You have 206 new emails, and there have been three updates to the Viable code repository overnight. David left a message: he will be in at 10, and you have a progress meeting at 3pm. Oh yes, and you ve been relocated to 78-1903 . Bill is happy to hear about the updates to the code repository,

but the chirpy voice makes him feel even more annoyed. Reminding himself to change personalities on his locator/announcer system, he heads towards his end of the building. The relocation is particularly good news; he needs to work closely with several other core team members if VSAD is going to work, but there have been no project dens available. Awareness announcements and ticker messages are all very well, but they don t really compensate for the real thing. Now, with any luck, the rest of the team core will be moving into the 78-1903 den along with him for the next couple of weeks.

As he s walking down the hall, Stacey pops her head out of her office. Bill! The locator system told me you d just arrived! Do you think we could have four or five meetings about the new hires over the next week? Bill groans to himself. How on earth is he going to find the time for interviews while he s killing himself trying to meet the VSAD deadline? While he s fixing the announcer personality, he decides, it would be useful to lock Stacey out of his presence/locator announcements until the VSAD crisis winds down.

Arriving at 78-1903, the door automatically unlocks as he approaches. One of the desks in the room is configuring itself for him as he moves in — over by the window, great, just where he likes to work, and the desk and chair have adjusted themselves to him. The computer logs itself into the network with his profile, and the smart surfaces on the walls and whiteboards boards reconfigure themselves to match the office to which he d been assigned yesterday — pinned up notices, pictures of the family and dog, the diagrams he d drawn on the whiteboard, and so on. Perfect!

10am: Coffee. Bill and David take a break. Bill and David (who d arrived shortly after Bill, equally happy about the new accommodations) are heads-down at Bill s desk working out the design implications of the changes to the Viable code updated from Melbourne. Using a combination of traditional computer-based displays on Bill s monitor, information accessed through personal information pads (wirelessly connected), and information they ve called up to be displayed on the various surfaces of the room, they are slowly uncovering the issues that need to be resolved. Rik, from the Melbourne group, is sitting in on the conversation. Mostly, Rik is working on getting the database management part of Viable to integrate with the Gale workflow engine, but since he built the part of Viable that s bothering Bill, he s keeping an ear on their conversation and occasionally chiming in. He s configured one wall near his desk to be a combined videoconference/shared worktop, so he can see and hear Bill and David, and keep an eye on their diagrams and code fragments. Occasionally he adds to the drawings they re building up. Smart walls are great, he thinks, all that real estate for drawing on, and your Mom can t even complain because the paint never really gets dirty! Each time Bill and David attempt a compile, there are complex type-checking failures on the code build. And each time, because he s subscribed to code build issues for this project, Rik gets a notification floating along the top of the wall next to his desk. He offers to help. I can rework the API for this section, and have it done in about 30 minutes or so. Why don t you guys take a break . Gratefully Bill and David make a run for the coffee shop across the road, leaving Rik to check the code out of the repository, change it and check it back in.

The coffee is wonderful, and Bill and David fall into an animated discussion of one of their shared hobbies: intelligent kitchens. In their spare time they re working on a prototype wired kitchen, in which all of the various appliances, utensils, etc are interconnected. Since they built the Elvin engine in the first place, it seems a useful application of their ubiquitous event technologies, and could make shopping and cooking much less of a chore. Suddenly, Bill s mobile bleeps. Glancing down, he sees he s been sent a message from the code repository. Rik s done. Finishing their coffee, they hurry back, careful to avoid Stacey (who they ve locked out of the location tracker). Rik s changes have made the problem much simpler, but not resolved it altogether more work!

3pm: Meeting Time! The whole team gathers for the progress meeting. Each group is in a meeting room at their local offices, all interconnected by both high- and low-speed videoconferencing. Each room gives the illusion of being equipped with a number of whiteboards, information displays, and other interactional features — but of course, since any part of the room is potentially an interaction/display surface, these are more conventions than anything else. Simon is a somewhat old-fashioned project manager, and likes to be able to put PERT charts on the whiteboard . So he s set up a whiteboard-like outline on one of the walls, and works within that. Bill is playfully scrawling graffiti around it by manipulating an image of the wall on his personal information pad. Rik is then adding doodles onto the result. When everyone is present , Simon gets Rik and Bill to explain the problems that have arisen with the Viable/Elvin integration, and the impact on people s schedules. The best part of this, Simon thinks, is that he can treat all the team members as if they re co-present in the one meeting room, and without the overhead of having to fly them all up to Brisbane, wasting a day in a packed schedule. It ll be tight, but it looks like they ll make it.

5.1. Reflections.

The focus of the vignettes has been on the ways in which physical and virtual space can be intermixed

once we step away from the monitor-as-interface metaphor of human-computer interaction, with its WIMP-style interfaces, to a model in which all the surfaces of a building are potentially a basis for interaction, and physical and virtual space are designed to extend seamlessly into one another. Thus, walls can be made to go away and become portals into offices across the country, information can be displayed where it s needed rather than on glass monitors, activities in the physical world are transmitted to others through the virtual (e.g. through the locator and tracking systems), and activities in the virtual world are made visible in the physical. Computers then become a much more natural medium for interaction, supporting the work practices of the group, rather than having the work practices of the group distorted to what s feasible within the constraints of the computing system. In many ways what we are proposing is close to Mark Weiser s vision of Ubiquitous Computing [16].

The key technology shifts that make this happen are the advances in display technology (and paint), a shift to highly-flexible, loosely coupled event-based information sharing, advances in small device technology (like locator tags) that can integrate with the event technology, a context management infrastru cture that can keep track of the relations relevant to the task being performed (group membership, what information relates to what, relevance indicators, etc), and an ambient environment that can manage mapping information to interactional affordances in a highly flexible and dynamic way.

5.2. The real world.

How does VSAD relate to the reality of augmentation-based interaction today? As we indicated above, the scenarios are based on a real-life tiger team which had to integrate similar software components. The team consisted of around 10 researchers spread across two floors and both ends of a long, skinny building. They had the usual mix of shared file servers, repositories, web site and email list. They made substantial use of Tickertape-based interaction to chat, be kept aware of changes to the shared repository space, ask and answer questions, be aware of who was around and so forth. Meeting room facilities, some equipped with state-of-the-art projection, file access and smartboard technologies, supported the team when needed. There was a reasonable amount of dropping in , clustering around a shared whiteboard in someone s cell for a while, discussing the project in the elevator, etc. And last, as the critical deadline approached the project team colonized a meeting space and set their equipment up there, creating a physical den for the last two weeks of the effort that complemented the virtual den in which the team had been working for the previous three months. The combination of physical and virtual affordances supported continual interaction among team members regardless of their location, as well as relatively painless transition to face-to-face interaction when needed. So the vignettes we described are achievable today, but within the context of current technology; and it s not unreasonable to assume that they will be technically feasible and reasonably affordable in the next decade.

6. Reflections

Stepping out of windows means stepping into cooperative buildings. A critically important point is that buildings are rich with affordances for encouragement of serendipitous, organizational and other forms of interaction. A building, through its space, plan and stuff (furniture, etc) [1] can help foster informal, serendipitous interaction, ambient awareness of what your colleagues are doing , and so on, and this provides a crucial backdrop against which work is accomplished. More formal and discontinuous interactions among members of distributed groups using technologies such as videoconferences at set times, emails, shared web sites, etc. do not have the richness of interactional affordance and convenience of use necessary to overcome barriers of distance. Augmentation technologies such as Elvin and Tickertape can be harnessed together with new interactional affordances in innovative ways to complement existing technologies and make informal, continual interaction at a distance possible.

VSAD shows that it is possible to build virtual dens and clubs for group activity. These are most effective when backed up or complemented by physical interaction and the ability to use physical meeting spaces, clubs and dens. In combination with more traditional uses of technology and physical spaces, it is augmentation technologies that will promote the greater flexibility and configurability of the spatial mix needed to support work.

The key then is in the mixture of physical and virtual space. In the same way that each organization is different, and therefore has traditionally needed a different mixture of different spatial types to suit its needs, cooperative buildings should aim to provide a mixture of the physical and virtual spaces in support of interaction. Ideally, this mix should be highly malleable, so that the spatial and virtual affordances can continually co-evolve, thus supporting the complex and continuous mixes of ever-changing spaces required by evolving organizations.

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