Evolution in Action:
HCI in a World of Pliant Systems

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Abstract

In 2020, digital systems will be an integral part of the interaction between people. They will help both in the maintenance of each person's individual perspective, and in the interplay between peoples' differing perspectives; they will help people and organizations respond effectively to local circumstances, and maintain the coherence as necessary for effective concerted action. To make this possible, digital systems will be far more engaged with their users, and will be far more supportive of the change, ambiguity and inconsistency intrinsic to social activity. Human-computer interaction will therefore come to be constitutive, not merely of the interface between person and machine, but of many aspects of human society.

Keywords

System evolution, enactment, socio-technical systems, multiple perspectives, dynamic stability, pliant systems.

Introduction

This paper is attempts to take a long term view of the evolution of HCI during the coming millennium— as long term as we can manage based on existing technical, social and design trends. We need a long-term view to provide a backdrop for today's HCI issues. Our society is being so drastically transformed by the exponential trends of digital technology that even a long term view can only span a few decades, but this emphasizes the need for making the effort to construct such a view.

In developing this long term view, we have avoided recounting mechanical extrapolations of existing trends, although of course we have used these extrapolations as underpinnings for our analysis. Instead, we have focused on putting together a picture that can help us find major new issues, gaps, or directions that are likely to arise in the new millennium— changes that give rise to new challenges and opportunities for today's HCI practices.

Major themes

Let us briefly review the major issues that we will see from many different perspectives in the body of the paper.

· Digital technology continues along exponential trends

Over the next twenty years, processor performance will probably increase by at least a factor of 4000, memory and disk capacities by even greater factors, and network bandwidth by a

factor of as much as a million. These exponential trends exceed our intuitive grasp, but they will profoundly reshape the environment for HCI design.

One curious aspect of these trends is that they have not led to proportionate advances in HCI. We believe that this is very significant and indicates major conceptual obstacles to fundamental advances in HCI. In this paper, we are optimistically projecting that these obstacles will be recognized and overcome.

· Digital systems are becoming constitutive in our social fabric

Digital systems mediate a significant amount of our social interaction today, and they will play a growing role. Furthermore, this mediation is increasingly visible. Digital systems have gone from an invisible role in completing our phone calls and interpreting the bits on our CDs to being a visible presence in many of our social interactions— purchasing, selling, reading the news, finding books or music, debating political issues, teaching and learning, talking to friends, and on and on. Furthermore, many key social institutions would no longer function if they were not coordinated by digital systems— telecommunications, finance, transportation, distribution of goods, high-volume manufacturing, probably health care, and many parts of the government, including the military.

Over the next twenty years, this dependence will become even more pervasive and total. When digital systems become such a large part of the social fabric, interaction with and through those digital systems becomes a major determinant of our social possibilities. So HCI itself becomes constitutive of our social fabric.

· Digital systems are becoming ubiquitous and sensorially transparent

As foreshadowed by the Ubiquitous Computing project at Xerox PARC [Weiser and Brown 1996], digital systems are already becoming pervasive, transparently networked, and differentiating into multiple specialized varieties. Just about everything will soon have an internet connection and a web server; anything that can't be wired will have a wireless connection.

At the same time, the architectural boundaries are shifting; interface devices are becoming "thinner", and more data and services are being stored "in the net". Increasingly, people will be able to treat their data and services as available wherever they are, with appropriate authentication.

These "thin" interface devices will gradually become more and more transparent to our senses, both capturing sensory impressions of the world around them, and providing points of view on other places. At the same time the range of sensory impressions will broaden somewhat. Devices will be able to capture 3D information, rather than just "flat" video and audio, and will probably be able to provide tactile feedback with minimal equipment.

All of these trends will tend to increase the integration of digital systems into everyday life to the point where the perspectives and opportunities for interaction they provide meld without identifiable boundaries into our ordinary world.

· Social organizations need to be responsive, coherent, and capable of scaling

People and organizations need to be able to respond appropriately to unexpected circumstances— they need to be responsive. Groups of people with common goals need to act in ways that reinforce each other, rather than interfering— they need to be coherent. And organizations need to be able to grow beyond small face to face interactions— they need to be able to scale.

Unfortunately, our current organizational mechanisms tend to reduce responsiveness to maintain coherence, especially as organizations grow larger. The consequence is that large organizations tend to be very poor at responding to unexpected circumstances. At the same time, these organizations have enormous power.

Furthermore, digital technology is largely designed to support coherence, rather than responsiveness, so it reinforces this pattern. As this digital technology exercises increasing influence over society, we run the risk that our key institutions will become increasingly rigid, restrictive, and brittle.

· People need support for their rich ontology

Unlike today's digital systems, people see the world in ways that are internally inconsistent, vague, unstable, and radically incomplete. They successfully deal with multiple perspectives, which are often mutually inconsistent or incommensurable, as they move from situation to situation. And at the same time, their views are continuously changing depending on context, experience, interaction with others, and their own needs.

All of these characteristics of human perspectives are at odds with dominant theories of digital semantics, which is theorized as totally consistent (within a given system), static, and unified by a single framework or "metalanguage".

As yet we have no workable theory of semantics that bridges the human world and digital systems. The result is that humans have to interact with digital systems in terms of their narrow semantics, and must even work to protect digital systems from the rich semantics of human society. This already causes many problems; as digital systems play a larger social role, these problems will become overwhelming.

· Social interaction depends on negotiated perspectives, relationships, and structures

Human relationships are negotiated in the event, and social structure is maintained by continual re-convergence on the "same" arrangements. Language continually morphs and drifts in use (and who knows this better than people working with digital systems). Even our most basic assumptions about ourselves and our world are continually shifting as part of this ongoing re-negotiation.

We have no place to stand outside of this shifting, evolving web of interactions. We cannot draw a line around some piece of the world and say "This is all that is relevant to our task." We cannot capture the structure of the world and freeze it into permanent form. Static systems rapidly fall out of synch with the social fabric and lose their value or even become dangerous. We must learn to build systems that can be pulled along by the continuing flux of social re-negotiation, and that can be integrated into the web of social interaction without damaging it.

· Flexible systems will depend on co-production

At least in the short term, we cannot build systems that fully participate in human interactions; nor do we necessarily want to. Conversely, people should not be limited to the level of interaction directly supported by digital systems. The solution to this apparent paradox is to interweave the social and technical, the human and the digital, through co-production of meaning and structure.

Today, systems define rigid islands of total consistency, coupled almost exclusively by human efforts. We need to integrate digital systems and human interaction at many different levels, on both smaller scales and larger scales than today. To do this we will need to make the

currently monolithic islands of digital systems permeable to human semantics, and at the same time give people ways to connect fragments of digital mechanism into larger units.

When people and digital systems are working closely together at many different scales, they will need to share initiative, contributing actively where they can be most effective, and asking for help where they are uncertain. **Both** people and digital systems must always have the option to ask each other for help; when a problem is difficult, this request for help may escalate to higher levels and may even lead to significant restructuring.

· People are better at performative interaction than purely syntactic interaction

Humans are incredibly good at sensing and acting in the world— running over rough ground, responding to the expression on someone's face, swinging an axe to split wood along the grain. These abilities were shaped by hundreds of millions of years of evolution and are deeply embedded in our nervous system. We will call this *performative* interaction; it tends to be "online", in the sense that it is carried out in real time, in the context of the task, and often through the use of the whole body.

In contrast, our abilities to correctly generate precise syntax, remember the spelling of terms, and calculate the results of arithmetic and logical operations are acquired only through considerable (and often painful) effort. Even when we are highly skilled, we are not as fast or accurate as an inexpensive calculator or card-sized dictionary. We will call this *syntactic* interaction; it tends to be "offline", in the sense that it does not demand real-time response, is typically independent of a physical task context, and engages only specific parts of the body (such as the eyes and the hands).

Ironically, most interaction with digital systems today is "syntactic"— it depends on the type of interaction where people are weakest. (Note that WIMP interfaces are nearly as "syntactic" as command lines.) People and digital systems will be able to integrate their activities much more successfully if we can engage peoples' performative abilities, and thus bring more of their bodies and brains into the interaction.

HCI Challenges

HCI can and should play a major role in addressing the eight issues discussed above. However, it faces two major challenges in taking up this role.

First, HCI has focused mainly on the surface issues of digital systems design; for the most part, it has left the system architecture to core computer science and information systems professionals. If digital systems and human activities are to be as deeply integrated as these issues imply, HCI must play a much broader and more proactive role at all levels.

We believe that this shift is inevitable, but it can occur through forethought or disaster. If HCI remains focused on local, surface issues, and digital system design continues along its current path, then eventually the gap between potential and reality will become so great that the current traditions of system design will be overturned. In that case, probably HCI will be pushed aside as well, and the integrative role will be occupied by some new discipline.

Second, HCI has inherited many of its methods and perspectives from related disciplines, especially computer science and experimental psychology. Unfortunately, it has inherited potentially disabling limitations from those disciplines as well. From computer science it has inherited a background assumption that systems must be based on total consistency, and thus a tendency to ignore or suppress the inherent richness, inconsistency, and complexity of human interaction with the world.

Similarly, from experimental psychology, it has inherited a commitment to experimentally and statistically tractable models of human interaction. Again, this tends to filter the complexity of human interaction in ways that suppress its inherent richness, and tends to direct attention away from human performative abilities, since these are difficult to capture uniformly and reproducibly in an experimental setting. Ethnographic emphases on "thick description" are a valuable counter-current, but until we can integrate thick descriptions more deeply into our systems, this emphasis on simplistic models of human activity will remain a problem.

HCI has gained much that is valuable through its relationships to computer science and experimental psychology, and we do not advocate rejecting these relationships. However, HCI now must rise to the challenge of more consciously and explicitly defining its own perspective on the methods and commitments that shape the integration of humans and computers.

Related Work

· Work Practice and Technology

Our thinking has been deeply influenced by studies of Work Practice and Technology (WPT) [Suchman 1984] [Suchman 1987] [Suchman 1995] [Tang 1991] [Isaacs and Tang 1997]. Rooted in North American anthropological views and practices, including ethnography and ethnomethodology, these studies have sought to observe and make visible the richness of "routine" work, and to show how work is accomplished in the face of an open-ended and ever-changing set of demands from the environment.

The examples in [Bowers et al. 1995], [Button and Sharrock 1997] and [Fikes and Henderson 1980] clearly illustrate our concerns about the limitations that digital technology places on the flexibility of work, and the difficulty of improvising with current digital systems. Scott Minneman's study of collaborative design [Minneman 1990] provides an excellent analysis of the essential role of ambiguity and vagueness in managing complex activities.

There is little in the WPT work that addresses technology per se, although recent work on responding through design to the reality that WPT has revealed is beginning to address how technology might have to deal with drift in perspectives.

Joann Yates [Yates 1989] describes in some detail the development of modern office organization as a mechanism of "control through communication": "During the period from 1850 to 1920, formal internal communications emerged as a major tool of management, exerted toward the goal of achieving system and, thus, efficiency. By the end of that period, control through communication was a fact of life in the workplace " [Yates 1989] p. xvi-xvii. Yates' account is especially significant because the organizational norms she describes have been transferred to a remarkable degree to the design of current enterprise computing systems.

· Participatory Design

Participatory Design [Ehn 1988], [Kyng 1989], [Greenbaum and Kyng 1991], [Bødker and Grønbæk 1989], [Bødker 1991], [Bødker 1991], [Grønbæk et al. 1993], [Grudin 1991] has roots in Scandinavia, where work with the trade unions was aimed at balancing the power held by management and workers in the design and use of computer systems by letting (potential) future users of technology participate in the design of that technology. Over the past two decades, this work has connected with the Work Practices and Technology studies in North America where the political dimension has weakened, resulting in a tradition of research and practice of on working with users to understand their needs and to design within that understanding. Out of this strong focus on users has come a deep appreciation of the diversity

of their opinions and needs. Yet, surprisingly for a tradition so steeped in supporting users' needs, PD has not question the assumption that the design process must produce a **single** system with a **single** perspective on the work. As a result, Participatory Design processes often must adopt a single perspective that will best satisfice the needs of an often widely diverse population of users.

· Tailoring

Some thinking in Participatory Design does admit the notion that the resulting system might be tailorable to the differing needs of different users [Bowers et al. 1995]. However, the tailoring considered is of two types only: selecting between predefined alternatives for system behavior, or providing "hooks" where programmers can add behavior to an otherwise fixed system. In each of these cases the ontology of the software itself remains unchanged.

Other work addresses tailoring more generally, seeing it as design continued in use [Henderson and Kyng 1991]. However, this work makes other limiting assumptions: that differently tailored systems will run independently, and that independently tailored systems will not collide with each other. Therefore it does not deal with the need for maintaining coherence between disparate, interacting perspectives.

· Computer Supported Cooperative Work

In the CSCW literature there is a general recognition that the subject matter of work is completely open-ended [Greif 1988], [Baecker 1993], [Beaudouin-Lafon 1999]. Therefore the computational tools that are proposed to support cooperative work are designed to provide a medium for exchange over which any subject matter can be sent (e.g., e-mail, video connections, images). As a result, most CSCW systems do not have subject matter ontologies built into them. Where a system is specific to particular subject matter domain, the designers assume that they must decide on a single ontology, just as with any other application program.

In some cases, researchers explicitly state their assumption that a single consistent environment is necessary: “Whichever variation is used, the abstract data model should be kept consistent across the entire groupware system, and synchronization must be maintained between the model and the individual views generated from it.” [Greenberg and Roseman 1999] p. 138.

However, in CSCW programs the medium being provided is a legitimate subject matter. So CSCW systems do have ontologies built in concerning the medium. Thus these programs may deal with addressing, synchronization, bandwidth. Negotiation of these matters is built into CSCW programs; [Dourish 2000] deals with making that negotiation more open-ended.

· Other perspectives

Terry Winograd makes an eloquent argument against the possibility of adequately expressing human meaning in a strongly syntactic framework:

“In projecting language as a rule-governed manipulation of symbols, we all too easily dismiss the concerns of human meaning that make up the humanities and indeed of any socially grounded understanding of human language and action. In projecting language back as the model for thought, we lose sight of the tacit embodied understanding that undergirds our intelligence. Through a broader understanding, we can recapture our view of these lost dimensions and in the process better understand both ourselves and our machines.” [Winograd 1991] p. 220.

However, in spite of his concerns, Winograd has not proposed any fundamental changes to the architecture of digital systems that will make them more suitable for expressing human meaning; indeed, he seems to accept the underlying design assumption of total consistency.

Rob Kling and his co-workers [Kling and Iacono 1984] have also expressed concern about the impact of computers on human values. They have placed more emphasis on the power and control relationships in the workplace. However, once again they take the immutability and total consistency of the computing infrastructure for granted:

"As the use of and dependency on an information systems extends throughout as organization, all members of the organization become potential actors. The various work groups and departments depend on each other to maintain and use the system accurately. They must cooperate to develop standard procedures that facilitate their interdependent use of the information system."

Note that in Kling and Iacono's view, not only is the technology essentially immutable, but the only available social response to the computing environment is to develop **standard** procedures, and once these are in place, they are regarded as fixed too.

Form of the Paper

Any effort at developing a long term view in an area changing as rapidly as HCI faces significant difficulties, and one of the most serious is imagining and understanding an environment very different from our own. We believe that understanding arises from an interplay between experience and reflection, and so we have adopted an unusual form for this paper. We have organized it around a scenario: four days in the life of a project manager in 2020. The scenario is presented in seven sections, each followed by a commentary—experiential context and reflective discussion.

To create a sense of the HCI experience in 2020, our scenario describes social context, interaction details, some underlying mechanisms, and many other particulars that we cannot know with any precision at this point. Compared with typical technical papers, of course, the descriptions of the interaction and the mechanisms are often relatively vague. We cannot hope to anticipate the specifics of actual technology in 2020.

While many of the details will turn out differently, we have chosen them to illustrate fundamental issues that we believe can be foreseen even over a span of twenty years. Through its "thick description" the scenario explores aspects of these underlying issues that would be difficult or impossible to convey explicitly. In the commentary, we will generally distinguish between speculative details provided as illustrations, and the deeper structure that we are claiming is implicit in major trends. If we are successful, even though perhaps no single detail will be as we describe, you will be able to make better sense of this deep structure and deal with it more effectively as it emerges.

The protagonist in the scenario, Olivia, is not an expert in the technologies or organizational theories of 2020; if she was, we could not write about her, because we would have to describe too many things that we can't anticipate or even understand today. Instead, she is a project manager through whom many different issues, organizational and technical, intersect.

The paper can be read straight through, in the normal manner. However, you may find it more interesting and easier to fully understand if you read the scenario through first, and then read the scenario and the commentary in the normal order. The scenario sections are highlighted with a gray background to make this easier.

Olivia's World

Olivia sighs as she finishes lunch at her favorite café. It looks like a slow week, but it's only Tuesday. Maybe things will liven up. So far the most interesting problem has been that contract interpretation issue with the MediaBank, and it seems like the contracts should have worked without her intervention— but she has to admit that she can't quite see how to build a good pattern that describes how they should mesh.

Olivia lets her mind drift a bit, reflecting on all the changes that led to her current work at Select Sprockets. When she was a student back in 2000 she expected to choose between working for a small company or a big corporation, but in the last twenty years most of the big corporations have evolved into "families" of smaller organizations of ten to three hundred people. Bigger groups seem to lose their responsiveness and ultimately their customers. Select Sprockets, with about fifty people, is pretty typical; it is part of the MegaMedia family, which evolved from one of the old corporations (or several of them— Olivia can't quite remember). Select Sprockets has close ties to several other organizations of about the same size in the MegaMedia family, but also works closely with organizations outside that family.

In retrospect it seems bizarre to her that companies in the early 2000s tried to do everything themselves; it's hard to imagine Select Sprockets hiring people to managing human resources, information systems, legal, finance, and manufacturing activities. How could they pay enough attention to their products? The outside organizations that handle each of these functions do a much better job than Select Sprockets ever could.

Olivia enjoys her job as an expediter and project manager for Select Sprockets— she keeps the business side running smoothly for some of the organization's "talent". Select Sprockets designs consumer products under various brands, usually (but not always) tied to the names of the projects designing them. The products have short life-cycles— from weeks to months— and consumer tastes are fickle, so people in Select Sprockets work hard to sustain strong coherence between their products and their markets by staying in touch with changing customer responses. The interaction always makes Olivia think of a dance between a Select Sprockets project, one or two of their competitors and a swarm of customers. The dances are complicated, precise and never quite predictable— just when everyone seems to be settling into an easy rhythm, an opening will come up and someone will improvise in an unexpected way. The best of her talent have an uncanny sense of how to guide the dance, anticipate opportunities, and throw in creative moves that give their project the lead, though only temporarily.

Olivia also enjoys the flexibility of her work. She can work from just about anywhere, although some places are more convenient. Much of her work involves meeting with project teams and other folks, and that often does involve some traveling— although it's a rare meeting where everyone is physically present. The idea of having to travel every day to the same office seems absurd, though— she remembers doing it when she first got out of school in the aughts, and she's sure she'd like it even less now. And Select Sprockets would be crippled if it's members couldn't live in widely different places and still work together.

She gets some tea and sits back with her tablet, looking over her projects. As she suspected, everything seems calm—hardly any uncomfortable spots; except for the Grinders, of course: she'd be worried if they **weren't** banging into at least some of the walls.

Olivia digs around and finds a guise* she saved over a month ago. She originally got it from Fred and tweaked it a little, but hasn't had time to play with it as much as she would have liked. She remembers enjoying it because it provided a nicely crafted dynamic summary of recent customer response to Select Sprocket products. Olivia turns over the guise; closed, it is a small dark green bundle, sheathed in Fred's distinctive eel-skin. She recalls that it provides auditory and tactile feedback, so she puts in her ear buds and slips on her tactile gloves.

Olivia runs her finger down the seam, and the guise opens up like a lily blooming. In the center, the pistil of the lily, is a loose braid, with strands constantly beginning and trailing off, but with an overall feeling of coherence and order. This shows the various products managed by one of her projects— Seahorse— which she must have been looking at the last time she used the guise. She zooms in some, and narrows her view down to the top of the braid— the last three months of history. In addition to the strands of Seahorse products, there are shadowy strands of competing products lying along the braid at points, and finer threads of customer response wrapped around the braid in an almost infinitely complex weave. She could keep on zooming in, and the guise would keep showing her more detail, but this is about right for now.

Olivia knows that the guise is showing her a very refined view of the petabytes (probably exabytes by now, she thinks) of customer interaction data that Select Sprockets has collected. Most of the data is recorded at the sites of Select Sprockets and its retailers. The raw data is enormously rich, containing everything from personal histories to reaction timings, but it is also enormously heterogeneous, since everyone follows wildly different courses of interaction, and the sites are continuously evolving. As a result, building guises for the customer data is a difficult art, but a very rewarding one. Olivia has occasionally had to delve into the lower level patterns that the guises use to build up views like these, but it's not her forte. The theories and mechanisms involved are just not her kind of stuff; she is into making projects work rather than machines.

Commentary on the World of 2020

The rate of change seems likely to remain high for at least the next twenty years, driven by the "creative destruction" of capitalism, and the exponential trends of digital technology. These mutually reinforcing economic and technical forces are continually increasing the fluidity of our social and material environment. To control change, we must harness these forces rather than resisting them; we must learn to build stability out of fluidity, to ride the waves rather than being tossed about by them.

Malone, Yates, and Benjamin, in an influential paper, [Malone et al. 1987] observed that digital technology makes commercial relationships easier to create and manage, and as a result, economic units tend to shrink or fragment. The trends toward outsourcing, spin-outs of smaller businesses, increased reliance on contractors, and the emergence of networked "virtual companies" are examples of this trend.

As these trends continue over the next twenty years, people will increasingly work in networks or federations at many different scales, coupled largely by digitally mediated interactions. The company in our scenario, Select Sprockets, is a federation of projects, and is itself federated with other companies into the MegaMedia "family".

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* A custom interface for visualizing particular structure in a data source. From guise: costume or external appearance.

Even today web sites and corporate transaction systems are collecting massive amounts of data, but this data has not yet been deeply integrated into the practices of most organizations. David Gerlernter [Gelertner 1991] has given us some interesting speculations on how things may change as this accumulation becomes more pervasive.

By 2020, with so many different interacting and changing systems, data collection will be far more massive, but the data itself will be complex and heterogeneous. Attempting to reduce it to uniform time series, or even to events within a single fixed model of the world, will throw away much of its value. Instead, the digital systems and group members, working together, will need to continually interpret it from different points of view, asking different kinds of questions, and seeking insights that will help them make better choices.

We believe a new framework is emerging that will enable richer ways of working with complex data. Work in neural networks, robotic vision, uncertain reasoning, and machine learning is rapidly converging on a powerful theory of statistical inference and model induction. For example, using this framework, researchers have been able to generate comprehensible models of complex processes from time series, [Brand 1998], and to create models of complex natural scenes from visual input [Ju et al. 1996]. These methods typically report how well a model fits, as well as the results it produces. While we do not believe that this technology can or should make machines autonomously "intelligent", it can make them more effective partners with people in coping with a complex world.

What will "effectiveness" mean in such an environment? The ultimate criterion is simply the survival and influence of each group. That, in turn, will depend on each group's ability to keep its members engaged, its customers and suppliers happy, its relationships with its peers healthy, and so forth.

In other words, groups at each level will be able to survive in the social and technical flux only by continually regenerating and renegotiating the relationships that hold them together and connect them with other groups. These relationships will be largely mediated **but not controlled** by digital systems. Thus digital systems and their human interfaces will significantly shape most aspects of everyday experience, interweaving the social and the technical into a new kind of institutional fabric.

Networked systems are already leading to a much more performative relationship between groups and their stakeholders. Busy web sites can make a change and get massive feedback from their users in minutes. Projecting this forward to 2020, the interactions between groups and their constituencies will be much more like a conversation or a dance than a conventional marketing campaign— realtime, open-ended, and richly textured. To be successful, groups will have to cultivate performative talents in their members, and provide environments that support performative interaction.

These groups will survive based on how well they engage their members' energy, creativity, and the richness of their experience. To retain its members and engage their abilities, the group must help them to enjoy their work. Thus the digital systems that mediate group interactions must satisfy people at many levels— aesthetically as well as pragmatically, and in terms of tacit sensory-motor intuitions as well as explicit symbolic understanding.

Given these trends, the activities of the group will tend to be an inextricable mixture of activities by the members and the digital systems. **Both** group members and digital systems will need to continually negotiate the terms of their interaction, questioning actions, asking for help, expressing values, and imposing constraints. Digital systems cannot be rigid and opaque; they must be inspectable, questionable, and ultimately revisable by the group

members. To achieve this, they will need to work in terms of values (comfort, discomfort, preferences, defaults), not just mechanical facts.

Today's software tends to be broken up by subject matter (e.g., scheduling, document preparation, or expense reports), introducing and reinforcing strong boundaries and fragmentation in work and views of work. In contrast, to achieve the integration required by groups in 2020, software will be constantly required to operate across these boundaries. As a result no single perspective will be able to encompass any given system; each will be composed of a partial integration of many different, partially consistent software elements.

The digital systems that knit these groups together must evolve with the group. Thus the work of reshaping and extending the digital systems is an essential part of everyday life. Users cannot be expected to work within a pre-defined system; they must continually re-create their digital systems through their interactions.

All the details of interaction that we give are likely to be wrong. Guises in particular are a speculative example. However, interface objects will need to be interesting and even beautiful, since they will form such a large part of their user's environment.

When Olivia uses Fred's guise she "sees" the data as Fred does— what matters, what things are similar and different, how to see and feel these relationships. However, she "sees" **the data**— they impose their realities on the guise, confirming or stretching it to fit. "Seeing as" is a process of mutual co-informing that creates new truths in one's perspectives on the world [Suchman 1984].

Fred's guise becomes a partially consistent part of Olivia's digital environment, just as Fred himself is a co-worker with his own style, beliefs, and skills in Olivia's social environment. This same sort of partial integration also appears in the life of each group member. Olivia's ability to work in a café, at home, in temporary conference rooms, and so on makes integration of work and life much easier and more pleasant. However, social constraints will continue to limit this flexibility. For example, Olivia would not want to use a fully immersive interface in a café, even if it is technically feasible, because it would be a serious imposition on those around her.

Olivia Diagnoses a Problem

There are no obvious problems, but something about the way customers are responding to the Heavy Metal project does feel a little odd. Olivia tries to figure out just what it is that bothers her. She quickly finds that just looking around with Fred's guise isn't enough to show her what she wants. Its analysis of the interaction data makes too many assumptions about the current market and customers. If there is a problem with Heavy Metal, it seems to be hidden by those assumptions. However, trying to understand it just through her tablet would be a pain; she needs more bandwidth and a more immersive interface.

Olivia, puts her tablet to sleep, pays her bill and walks a few blocks to a local office where she likes to work. As Olivia comes in through the door, the office focuses on her. There's a brief pause as the office recognizes her and brings up her own office persona (with no face— she finds those way too phony). Her office voice says "Good afternoon, Olivia" and she automatically replies "Good afternoon" as she pulls her tactile gloves on. She sits down, the office locks onto her eyes and the table and wall dissolve into a dimly lighted space, with her modified version of Fred's guise folded up just in front of her. She opens it up again. The resolution is much higher than she could get through the tablet; in addition to the better

interaction devices, the guise has by now had more time to work through the analysis of the data.

She focuses the guise on the recent Heavy Metal history that seems odd, and locks it so that her investigation won't change the setting. Then she puts a probe into the guise and begins looking for the patterns that the guise uses to model market response to Heavy Metal.* Her office shows her the internal organization of the guise as a network of nodes whose size and clustering reflect how much they contribute to the guise's current display. Each of the nodes is a small view of the associated pattern, showing its current state; if she focuses on a single node, she can usually tell how it is contributing to the display. Olivia thinks of this display as a "sea of nodes" because the ripples and swirls remind her of flowing water. She swims through the sea, getting a feeling for how Fred has put the guise together, and how the guise itself is interpreting the current behavior of Heavy Metal's customers. After a little while she zeros in on the service and support patterns. By suppressing the contribution of some patterns and looking at what changes in the display, she eventually finds a pattern— *Service is a Feature*— that seems to be most involved with the aspects that have been bothering her.

Olivia pulls out *Service is a Feature* and removes the probe. She looks at the pattern as a diagram of forces interacting— in this case, the customer needs for service, the costs to the project of providing it, and the consequences of the service strategy on price, timing of product introduction, usability, etc. As Olivia focuses narrowly on each strand showing customer response, the diagram reconfigures to reflect the balance of forces at that point, as modeled by the pattern. Olivia understands the concepts represented by the pattern intimately— she has been living with these issues for years. As she gets a clearer sense of what's bothering her, she reworks the diagram—and occasionally sub-diagrams representing subordinate, related patterns—to reflect her deeper understanding of the exact problem in this case. As Olivia changes the pattern, the presentation generated by the guise changes correspondingly.

By tweaking and extending *Service is a Feature*, Olivia gets the guise to pick up some definite discomfort in the customer interaction with Heavy Metal over the past month. Some of the customer responses are beginning to shift in ways that hint at problems in Heavy Metal's rapport with them. Olivia thought that Heavy Metal was doing really well, and indeed the discomfort is a bit subtle so far, but it is getting worse fast enough to be worth investigating.

After probing the guise a bit more and tweaking a couple of other patterns, Olivia is satisfied. The location of the problem is now clear; in the last few inches of the braid— about the last month— a few strands of the customer response change gradually from cool sea green to an angry red. Several other strands look like they are in the early stages of a similar shift. After a bit more refining the guise, Olivia feels she has a good sense of "where it squeaks"— the values embodied in Heavy Metal's customer service policies are drifting out of synch with the

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* We are using "pattern" in the sense described by Christopher Alexander [Alexander 1979] ,p. 263-265:

> "...to strike the balance between being too narrow and too loose, you must express and visualize a pattern as a kind of fluid image, a morphological feeling, a swirling intuition about form, which captures the invariant field which is the pattern....
>
> A pulsating, fluid, but nonetheless definite entity swims in your mind's eye. It is a geometrical image, it is far more than the knowledge of the problem; it is the knowledge of the problem coupled with the knowledge of the kinds of geometries which will solve the problem, and coupled with the kind of feeling that is created by that kind of geometry solving the problem. It is above all, a feeling— a morphological feeling."

profile of its customers. In addition to its targeted consumers, Heavy Metal has begun attracting some more sophisticated business customers, who would like their products sooner and cheaper, with less bundled service.

Commentary on Exploration and Diagnosis

Engaged with the guise, the tools that allow her to modify it, and the patterns that capture its semantics, Olivia is practicing her craft, and is engaged in a reflective conversation with her materials [Schön 1983]. The guise and its patterns objectify complex and subtle issues of customer demand, organizational policy, and business strategy.

Once again, the guise is a speculative example. Our use of patterns is also speculative, but they are a much more important part of our worldview. Alexander developed his original pattern language to support collaborative design. As such, patterns must express design intuitions, and at the same time function as combining forms to allow the flexible composition and interaction of design elements. We believe that patterns have the potential to serve as a means for collaboration between humans and digital systems that overcomes many problematic aspects of current syntactic interaction mechanisms. We have explored the underlying technical issues in some depth, but unfortunately do not have the space to discuss them in this paper.

The guise and other interfaces we describe allow Olivia to develop her own interpretations and explore them. She is able to push things around and see where they bind (color change reflecting forces), hear where they "squeak" (auditory feedback) and feel where there are rough edges (tactile feedback). This shift in emphasis from thinking / describing to sensing / doing aligns well with the capabilities of both parties in the interaction. Much more of the human brain is devoted to supporting sensory-motor skills than symbol manipulation. And on the machine side, even today sheer computational capacity is outstripping the ability of programs to use it; most machine cycles are spent doing nothing.

Olivia is actively engaged, sensing, exploring and adjusting without explicit articulation, based directly on her intuitions about the structures she is manipulating. The engagement of her senses enables the full power of her human preconscious perception to be harnessed in dealing with her material. Because Olivia encounters issues in concrete, sensorially rich form, she can play with the problem, develop an almost physical intuition about it, and capture it in specific adaptations of her tools. Thus, when Olivia plays with the braid, and gets the feeling that Heavy Metal is odd, she does not have to describe what that oddness is, and she is freed from having to squeeze all interaction through the channel of articulation.

At the same time, because the guise and its patterns are "live", tied into vast computational resources, huge data stores, and statistical tools that can model that data, Olivia's craft is practiced in a very powerful, responsive environment. The result is a new type of interaction, with the depth and unconscious fluidity of craft skills, the compositional power of symbolic methods, and the malleable dynamic of digital systems.

In contrast, today's systems give their users few means to talk about their activity or their interface. The activity of the system is reflected in the interaction only where applications explicitly call it out in application terms (e.g., progress bars presenting copying), or where operating systems show mechanics (e.g., flashing icons presenting disk activity), and it is only weakly possible to use these presentations to control the activity (e.g., buttons for canceling the activity in its entirely). Some help systems give users mechanisms to refer to elements of the

user interface (such as tool tips, balloon help or coach marks), but they only provide information; they don't provide ways to drill into or change the software itself.

Olivia's exploration depends on her ability to refine her instruments as she goes. The guise and the patterns are subjects for her as much as the customer interaction data. To support this reflexive power, Olivia and her system must be able to deal with their own action and interaction as well as external content; people and machines must be able to talk overlapping languages, and must be able to refer to each others' activities. Such self-referential behavior is common in human conversation, and is essential to our ability to manage our social interaction; it is just as necessary in managing our interactions with digital systems.

Just as the guise and the patterns are user interface tips of huge data resources, so Olivia's tablet and office are just tips of a huge computational infrastructure. Olivia's environment is permeated with digital communications. Her digital environment is available wherever she chooses to work (subject to authentication, which could be as simple as recognizing her retinal pattern). Furthermore, her digital environment is active; processes continue even when she is not involved.

This introduces many new challenges. The "objects" Olivia is manipulating must be transferable between radically different interaction environments (such as her tablet and her office). When she initiates a "heavy-weight" activity, such as re-analyzing a few exabytes of data, which may take a long time to complete even in 2020, she gets incremental results quickly, and then gets refinements over time.

Olivia Attempts a Repair

Now that she has a fix on the symptoms, Olivia needs to track down the source of the problem. She asks the office to show her the Heavy Metal operational patterns that strongly match her refined definition of the problem. She quickly gets a display similar to the earlier "sea of nodes," but this time organized by strength of match to her definition. She moves the two most similar patterns on top of each other, and the system shows her discomfort markings where they differ. After looking at the sources of difference, Olivia marks some of the elements of one pattern as "don't care" and adds a variant sub-pattern in one place, and the two patterns merge, with the "don't care" sections grayed out. The change ripples through the sea, allowing some patterns to merge and moving many of them closer together. Olivia again selects the most similar un-merged pattern and figures out how to generalize her new template to get it to merge. After a few more merges, over half the initial patterns have merged, but the most similar one remaining can't be merged with her template unless she grays out some of the key items that seem to underlie the problem. She creates a new template by merging the two remaining similar patterns, and fairly quickly has absorbed most of the remaining patterns into her second template. She inspects the six remaining un-merged patterns and decides that they probably aren't relevant after all, so she deletes them.

Olivia steps back a bit and looks carefully at the two templates she has created. She overlays the definition of the problem onto the templates, and the system highlights the parts of the templates that match the problem definition. She can easily see, based on the highlighting, how the existing policies cause the problem; she can also see some changes that would probably eliminate it. She thinks that Select Sprockets hasn't reviewed its service policies for too long; she had not noticed the common themes she has just found, but now that she's brought them into focus, she can see that this was bound to cause problems soon. She's just glad she noticed it before it became a crisis.

Olivia realizes she has built up quite a bit of structure, so she creates a history thread and names it “Metal bending”. She associates all the work she has done so far with the thread. From now on, her changes to patterns will affect only this thread, unless she commits them (with proper authority) to a larger context in Select Sprockets.

By this time Olivia feels she has spent enough time just gathering information; she wants to try changing things. She begins by tweaking her two template patterns to fix the problem. When she’s satisfied with her changes, she has them propagate the changes to the entire set of patterns that they summarize. In several cases, the interpretation of the changes is too ambiguous for the templates to handle it automatically, so they ask her for help, but she’s able to figure out how to handle each of the cases fairly easily. She goes back and changes a couple of the variant sub-patterns in her first template so it handles some of the cases automatically, and thinks that this area is **definitely** due for a cleanup.

Now, she wants to see how these changes would play out in practice. She needs to see how customers **would** respond if they were encountering products with these service policies instead of the ones Heavy Metal is actually offering. She has the system simulate a typical mix of customer profiles. Of course, it wouldn’t be all that useful to simulate a one or a few customers; she needs to simulate thousands of them, and look at their typical range of behavior. Using the huge Select Sprockets interaction database, the system can generate probability distributions for customer decisions with reasonable accuracy, and using these distributions it can simulate how a whole population would interact with the new policies.

The simulation results take a few minutes to come up; the system has to go back over the interaction database, generating distributions for all of the decisions customers might make, based on the changed policies. Olivia uses the time to order dinner to be delivered at her home in an hour and a half; she wants to eat with Tina and help with her homework.

The system presents the results in the format Olivia normally uses for a normal customer history summary: a river of branching and merging rivulets, containing all the customer histories in parallel. The presentation is much lower resolution than the normal history summary, since the simulation introduces significant uncertainty, but still Olivia can see immediately that the new patterns lead to a significantly more coherent relationship between Heavy Metal and its customers.

Since the new policies pass this basic hurdle, Olivia decides to try another test. She puts the new policies into a simulation of Select Sprockets business processes. To get quick results, she sets it up to only do detailed simulation of Heavy Metal and run the rest of the organization at a much coarser level. Olivia has often found this simulation useful. It doesn’t attempt to be “smart” and simulate human judgement, so it is not very realistic, but it gives her a sense of whether a change she is considering will cause process conflicts.

Almost immediately, a new pattern comes up with major discomfort blazing on it. Looking at it, Olivia quickly realizes that is tagged as a basic family pattern— that is, one of the patterns widely shared by organizations within the MegaMedia family, and not to be modified lightly. Looking more closely, she sees it is named *Good Service Makes Strong Relationships*.

Olivia quickly realizes that she can’t resolve this issue by herself; family values are too heavy to mess with on an individual basis. She’ll have to call a group meeting. Since it’s already getting late, she decides that this is a good time to close the office and head home.

Commentary on Modification and Testing

Throughout Olivia's investigation, she and the system are working fluidly together, with initiative moving back and forth from moment to moment. The system continually presents relevant information in a form that allows Olivia to use her judgement effectively to move things along. Since the system makes alignment visible and roughness tangible, she can often determine when a given fit is good enough with little or no explicit thought. At the same time, the system ripples changes through while she is working, giving her the benefit of an active environment, instead of one that only moves when it is pushed. Thus she and the system can work together in real time.

We call this fluid collaboration *enactment*. While enactment requires the system to take an active role and function according to its internal values, it is almost the antithesis of autonomous "intelligence" on the part of the system. Olivia does most of the creative work and contributes much of the moment to moment judgement and guidance. None the less, the system plays an essential role in making enactment possible.

Enactment allows Olivia to come up with possible solutions to her problem largely through synthesis, progressive constraint, and incremental generalization. Today, the same creative work would require building possible solutions from scratch, perhaps with help from some type of interactive editor and checker; such creation *ex nihilo* makes much greater demands on the memory and skills of the creator. Furthermore, this use of enactment results in a solution that is inherently contextualized and traceable to its sources, making later revision, extension, or critique much easier.

Enactment can be focused at many levels, and can shift levels easily. Olivia can treat patterns as objects, sliding them around, adjusting where a match should be tried, and then she can break into a pattern and change it (e.g. bend the structure, replace a sub-pattern, waive a requirement) to make it fit the case at hand, without changing environments or tools. This is already easy for people, who move gracefully in conversation from one level to another; we need to make it possible in our interactions with our digital systems.

Both Olivia and the system are constantly judging when a result is **good enough**. Unlike current "truth value" semantics, most values and relationships are continuous, rather than simply true or false, one discrete value or another, present or absent. This "play" in the system opens up room for partial inconsistency, and thus it requires ongoing management— usually implicit, sometime explicit— of the coherence of the system.

Since the system monitors its own confidence and coherence, it can appeal to Olivia for help when it can't find a "good enough" result. Happily, the kind of self-monitoring we need arises naturally out of bayesian statistical modeling. This joint effort to keep the enactment "good enough" produces a through mix of the human and the technical, co-production of a rich, often-unarticulated fusion of human and machine.

A system that permits fluid, non-deterministic change must also give users control over the propagation of change. On one hand, Olivia must be able to keep her changes bottled up in her private variants of projects. On the other hand, her changes must still dynamically merge with the complexity of the real projects: initially with the customer interaction data, and then with the full structure of the Heavy Metal project.

Also, as with any social environment, the system contains barriers to change— but like social environments, and unlike our current digital systems, these barriers are contextual and

conditional, open to analysis and negotiation. They can be tested, worked around, and even modified when appropriate.

As Olivia moves from creating a potential solution to investigating its consequences, the active role of the system becomes even more important. Many problems need to be understood in terms of complex system dynamics, populations of potential interactions and distributions of possible results. These are very difficult for the human mind to grasp directly, so we often grossly oversimplify our evaluation of proposed solutions, frequently with very unfortunate results. (We have only to look at typical political debates to see the absurd consequences of this characteristic error.)

In our scenario, this oversimplification can be reduced because the system takes care of the complex dynamics, and presents the results in a form whose complexity is well matched to the human perceptual/ motor system.

Olivia and Her Daughter

It's a pleasant fall day, so Olivia enjoys the walk home, and arrives a few minutes before Tina is dropped off by her carpool. Tina is enthusiastic about the project on algae blooms in local lakes and streams that she is doing with six of her classmates, and several other groups scattered around the country. She spends a while showing Olivia some of their early results on her tablet. The data the students collect isn't as high quality as the data from field biologists, but there are more of them and the statistical modeling integrates the data in ways that make up for their inexperience.

Olivia remembers when she was about Tina's age, in sixth grade; school seemed so much more narrow and regimented. She could only work with the teachers and students in her own school, and the curriculum often seemed either boring or impossible. She wishes she had been able to work on projects the way Tina does, collaborating with younger and older students, and even professionals and adult volunteers. Of course, in those days the organizational problems of having lots of little groups doing different projects would have been overwhelming, and it would have been almost impossible to make sure she learned all the required topics and skills in any given year.

Tina's school uses the same kind of coordination that helps Olivia keep Select Sprockets in dynamic balance. Of course in the school the "group members" change every year, and the goals are very different, so the systems don't look very similar, but their underlying technology is almost identical. Olivia enjoys volunteering occasionally to help out when the school needs some help reworking its project management.

The local delivery van comes by with dinner just as Tina is finishing her demonstration, and they discuss Olivia's day and their plans for the weekend. Olivia's mention of Heavy Metal reminds Tina that she wanted to show Olivia a performance that she and some friends put together using Heavy Metal instruments. None of the kids know what "heavy metal" was, but they like the retro sound of it.

Tina has a Jaguar, one of the high-end instruments— Olivia has connections, after all. She and her friends have set it up to watch them, and improvise music as they dance. They often get together at one or another of their houses, but Alley, one of Tina's best friends, recently moved away, so she participates remotely.

First Tina replays a piece that they created recently; the light show creates an impression of the dancers through silhouettes. Of course Tina could show her a 3D recreation of the dance, but

she thinks the light show is more interesting, and Olivia agrees. Then Tina shows her the music improvisation patterns that she has set up, and they have some fun tweaking them in various ways— ultimately replaying Tina's initial piece with an out of date Herky Jerk style which is so ridiculous that they both go off into gales of laughter.

Tina settles down to work on some problems in the analysis of the algae data that the team needs tomorrow. Olivia, still chuckling, thinks that Tina shows quite an aptitude for getting interesting effects out of the Jaguar— and the pattern language she built to generate the music was also very nicely put together. Probably the school is aware of Tina's abilities, but Olivia thinks she'll talk to them about finding some projects that will give Tina a chance to really stretch her wings in pattern-based art.

Olivia looks at the time and remembers that her quilting group is starting in a few minutes. She goes to her office and gets out her fabric and the blocks she has already done. She has been quilting with these friends for years; originally they got together at each others' houses, but some of them have moved too far away, and anyway the logistics get difficult— tonight she wants to stay home with Tina, for example.

She connects to the group and starts to set up her cutter; Raymond is the only one there and they chat while the others trickle in. Recently almost everyone has been showing up— the new quilts have been a lot of fun. They started out using other people's patterns, and then worked out some of their own. Just in the last year they've started to take real advantage of the virtual environment to piece the quilts, and come up with some terrific designs— the current quilt is made with something called Penrose tiles, and it bends Olivia's mind a bit every time she looks at the part they already have done. They long ago decided to keep the piecing physical, but she's glad she can rely on the cutter to get the angles and curves right, and she enjoys working out the fabric choices in their shared environment.

After two hours, the group is still going strong, but Olivia has to fold for the evening; she knows she'll have a big day tomorrow.

Commentary on Activities at Home

Many of our themes transpose naturally into dimensions of life beyond work: school, entertainment, socializing, and no doubt religion and local politics. Probably, in fact, the pervasive deployment of the type of digital systems we discuss would make possible a much deeper integration of these dimensions of life than we describe here, but it is beyond our current ability to imagine how this would look in practice. In any case, viewing our themes through the prism of home, we can see some aspects that were less obvious at work.

In 2000, school is, if anything, more regimented and bureaucratized than work. This is ironic, because the nominal subjects of school activity, the students, are further from being standardized and repeatable than most business subjects. We believe that this regimentation can largely be attributed to the need to manage large numbers of students with relatively few teachers and to organize the whole process with little more than pencil, paper, and fallible human skills and memory. Current rigid computer support for scheduling, testing and student records reifies and exaggerates these problems. In contrast, use of more flexible digital systems might help adapt schooling much more closely to the needs, backgrounds, and preferences of individual students.

Since most life activities will be collaborative, school activities need to teach collaborative skills. Students will be far more motivated and engaged in activities that have real social consequences, and even relatively young students can participate in valuable social activities.

Again, more flexible systems may help organize these activities, making it feasible to evaluate their effect on the student, and to ensure that each student gets adequate and balanced coverage of the appropriate skills and knowledge.

In societies without electronic technology, artistic performance skills are widely taught, practiced, and enjoyed. Historically, electronic media technologies have emphasized reproduction of artistic performances immensely more than creation of new performances, and partly as a result, performance skills have become much more professionalized and less widely practiced. However, this balance is beginning to shift. Even now computer systems are making audio and video production much easier, and many more people are producing them for the enjoyment of their immediate social group. This trend will gain tremendous momentum as digital audio and video become easy to pass around on the web. Even video games are a sort of performance technology, albeit on the borderline between art and sports, and the recent evolution of multi-player, role-playing, and simulation games offers interesting suggestions of future performative potential. As systems become more powerful, and as technologies like video games, music synthesizers, and 3D capture merge into general performance systems, the balance is likely to shift further.

Artistic performance is an especially interesting area for us, because it shows most dramatically both the potential and challenges of real-time, performative user interfaces. Performing artists want to improvise, to invent new effects and to continually reshape their systems to keep up with their evolving ideas. The history of music synthesis offers many interesting examples of the special demands made by performers on digital systems [Smith 1991]. As digital systems support a wider range of media and types of artistic expression, these demands will have a wider and deeper impact on HCI in general.

Social interaction is already being influenced by digital mediation, especially email and chat, but also discussion groups of various kinds and the world wide web. People have an easier time maintaining relationships in spite of geographical and logistical challenges. However, digital mediation of realtime social interaction is still extremely primitive, as anyone who has had to use today's video-conferencing knows.

When people are in physical proximity, they share many experiences beyond seeing and hearing each other; however most of these, such as smelling the same flowers and feeling the same wind in their hair are probably beyond our technology even in 2020. Still, people are likely to explore richer forms of realtime interaction than just video and audio. The types of interaction that will be satisfying are difficult to predict, because they depend so heavily on the fine details of how people manage realtime interaction, which is still very poorly understood[Cassell 1998]. However, we believe that performative, flexible HCI will be essential in any digital system that provides satisfying realtime social mediation.

Olivia Prepares for a Meeting

The next morning, after she packs Tina off to her learning group, Olivia starts to organize an effort to deal with the policy problem she's uncovered. First, she checks in with the Heavy Metal team. Andy and Maureen are available, and Olivia shows them the problem she has discovered. They are happy to have her working to fix the problem, but obviously don't particularly want to participate; they are much more interested in focusing on their design challenges and customer requests. Olivia confirms that she has their proxy for the decision meeting she plans, and signs off. She notes that there will probably be cultural stress in the team as they get more business customers, but that is an issue for another day.

Olivia concludes that she will need to call a Select Sprockets policy meeting to decide on a fix. She spends a little time with one of the organizational views figuring out who needs to participate. This is likely to be a decision with significant business impact and risk, so it will need to be properly authorized, and she wants to make sure that everybody in Select Sprockets will be represented. With a little fiddling, she finds eight people who collectively have all the proxies she needs and who are all likely to be available, and then she puts a group meeting on her calendar, with a brief problem description and a promise of more soon. Since this is potentially urgent, she schedules the meeting for two hours any time Thursday or Friday after 10AM, knowing the participants can work it out, and adds in a request for Meeting Maker service, so they'll have rooms reserved.

Next, she needs to create a summary of the problem to provide background and an agenda for the meeting.

Working from the Metal Bending thread that records the history of her session, she pulls together the key elements: the guise that identifies the initial discomfort, the mapping of her tailored patterns into the Heavy Metal operational patterns, her modifications to those patterns, and the coarse simulation that identifies the conflict with *Good Service Makes Strong Relationships*. She also does a quick search and finds six similar operational patterns elsewhere in Select Sprockets that may start to cause problems, and adds them to her summary. Since she was using the two Heavy Metal templates as the search image, and she had already mapped the problem pattern into those patterns, the equivalent mapping into the other patterns is essentially automatic.

Next she pulls in some history for the *Good Service Makes Strong Relationships* pattern, and finds a good way to show how several different organizations in the MegaMedia family have used it, so that the other people in the meeting will quickly be able to get a feeling for the variation, the core of consistency, and how both have been changing over time.

That should convey the essence of the problem but Olivia knows people will also want some idea of what to **do** about it. She starts to sketch possible solutions, beginning with a simple pattern that simply changes the policy to suit Heavy Metal, which she calls *Separate Service Products*. After looking at how other organizations with similar products handle their service policies, she copies one of their patterns that seems fairly typical, *Service to Fit the Customer*, and adapts it to the Select Sprockets environment. Olivia knows that she'll need more alternatives, but two is enough to get people thinking.

She integrates her initial sketch alternatives into the summary, and that gives her some ideas about how to make them more complete. Finally, she highlights the conflicts between each alternative and *Good Service Makes Strong Relationships*. The summary isn't as graceful as some she's seen— she isn't a pattern poet by a long shot— but it gets the point across clearly enough, so she puts a reference to it in the meeting proposal.

It's now early afternoon, so she takes a walk, does a few errands, and sits in her café for a while catching up on other business.

As she's getting ready to head home, Olivia checks her calendar, and sees that the meeting seems to be converging on Thursday afternoon, although possibly Evan can't make it then, which would be unfortunate. Steve has pushed his version of the meeting into early morning, as usual, but Olivia knows he'll grumble and go along, as usual, so she doesn't change the boundary. Meeting Maker has found a good place where most of the participants can get together, although three will have to be virtual, and it's only about a five minute drive.

After dinner with Tina, she checks her calendar again, and sees that most participants can meet at 1:30 Thursday, but that Evan can't make it then; he's only available in the late morning her time. Olivia splits out a meeting with him for 11AM.

Commentary on Organizing Group Activities

Organizations dealing with rapidly changing, fluid environments will need flexible decision processes that encourage local initiative. Any given decision should be made by the people with the right information and responsibility, while minimizing the burden on people who don't need to be involved. The trick will be to identify the people who need to be involved and help them to make the decision as effectively as possible, and then to implement the decision as smoothly and rapidly as possible. Digital systems will need to enhance this flexibility and also help to maintain coherence that might otherwise be lost through local decision making, preserving accountability and security.

To explore this issue we speculate that Select Sprockets authorizes decisions based on review by individuals who hold delegated authority, or "proxies"— some authority delegated from above, and some delegated from concerned groups within the organization. So, for example, Olivia holds the Heavy Metal team's proxy for this decision, while they might choose to be personally involved in more product-related decisions. They trust her with their proxy partly because they are confident she will involve them when appropriate.

Olivia uses Select Sprockets' digital systems to find people with the necessary proxies to make the decision she needs. When things change, or changes are proposed, knowing who may be affected is essential for maintaining coherence across (and beyond) the organization. Olivia needs people with "skin in the game"; those who not only have the knowledge and experience to make an informed decision about change, but who also have the ability to get their part of the organization to adopt and implement any such changes if and when that becomes necessary. Finding these people would be far more difficult and less reliable without digital support, leading to a more static, "org chart" based decision process that would probably be significantly less speedy and effective.

The decision process is further supported by Olivia's creation of a "live summary", containing tools for viewing the relevant state of the organization, reviewing the existing and proposed policies and their interaction with other business processes, and simulations of the impact of the policy. Such analysis is undertaken now, but only in the case of very large, expensive decisions. If Olivia had to create such a summary from scratch, or by studying the entrails of an opaque set of poorly integrated software "islands" (as exist in most enterprises today) it would take weeks or months, to the extent that it would be possible at all. Olivia can accomplish her task in hours because much of the activity of the organization is mediated by digital systems already, because patterns can serve as a *lingua franca* for searching and binding disparate system elements, and because the resulting descriptions can easily be explored, reified, and presented in human-comprehensible form. Today's systems have only a thin description of the world; Olivia's ability to create meaningful analyses and proposals depends on access to the much richer descriptions generated by patterns from massive underlying data.

The combination of authorization by proxy and discussion based on extensive data and strong analysis is reminiscent of Cetina's concept of "management by content" [Cetina 1999]. As Cetina says, this type of organization "maintains participants' proximity to [organizational tasks], and… substitutes, where possible, object-oriented structures for social authority structures." ("Object oriented" is used in the social science sense, not the computer science sense, although there is an interesting overlap from our perspective.) In Cetina's examples, the

objects are complex and expensive scientific instruments. Similar examples can be found in large software development projects, where activities are largely coordinated around digital representations of software configurations, bug tracking databases, automated test processes, and so forth.

We believe that as business processes are assimilated to digital systems, and as these digital systems themselves become more inspectable and manipulable, this type of "management by content" can be extended to a wider range of business decisions. As this happens, HCI will become central to the decision process itself.

Digital mediation can also help in organizing ordinary social events, such as face to face meetings. Here again, however, we see a need to make the digital system permeable to human intentions and observations.

When Olivia makes a meeting proposal, she indicates her preferred times and dates, and her intended agenda. However, this is not a fixed specification, it is subject to negotiation between the participants. Other participants make their own proposals, and through the social interaction, mediated by the digital system, the group converges on a time— or doesn't, perhaps leading to multiple separate meetings, as in this case.

In the process of negotiating, each of the individuals can use the information provided by the system, such as a display that consolidates current proposals, but they can also use their own background knowledge, such as Olivia's expectations that Steven will grumble but go along with the crowd. In the end, the convergence may be achieved by solutions the system could not determine, such as Olivia's decision to meet separately with Evan. However, in a complex environment, with many demands, the meeting might not come together at all without support from the system. Both the human and the digital contribution are necessary.

To facilitate this negotiation, the system needs to be as permeable to human intention as possible. People need to be able to indicate how committed they are to a particular preference or dislike. They must be to be able to indicate uncertainty or indifference as well as specific decisions. All of these are conveyed in normal face-to-face interaction. It would be unrealistic, and even pernicious, to presume that the digital system could "compute" with these indications, but that is not its responsibility— it need only consolidate them and present them to the negotiators, to facilitate the social process.

Olivia Runs a Meeting

In the morning, Olivia sees that that Lily has sent in another possible solution, *Service is the Product*. She can quickly see that Lily's proposal is reasonable, so she adds it to the problem summary. She's grateful to Lily for taking the time to craft it nicely so the bindings and the potential conflicts are clear.

At 11, Evan calls. He has reviewed the summary she put together, and makes a few suggestions about refinements, but basically agrees. In discussing the three solutions so far, and the history she has collected, they notice that the solutions can be viewed as defining two dimensions, which suggests that they find another approach to fill in the fourth quadrant. Evan proposes a generic solution that fits, which Olivia will be able to quickly sketch up. They agree that four is definitely enough! Evan leaves her with his proxy for the larger meeting, which is a clear sign of his respect, and Olivia is pleased.

Olivia gets to the 1:30 meeting a bit early, with a few butterflies in her stomach, since she's only participated in a few efforts to hack family values, and has never led one herself.

However, she does feel it's a pretty clear case, so she's not **too** worried. The room itself is familiar— one that Select Sprockets uses fairly often for face to face events— and she knows the proprietor a bit, so they banter about the recent chaos in virtual access and how crazy the kids are getting. By then the others are there or on line and it's time to begin.

As usual the meeting starts with a presentation of the problem summary, given by Olivia as the convenor. Everyone has a reference to it already, but of course most of them haven't looked at it in depth so she takes it from the top. The presentation revolves around showing the Heavy Metal project data, demonstrating what current patterns are doing, and simulating what the four proposed new patterns would do instead. Most of the questions along the way she's already anticipated and they are answered in her summary, but the participants ask a few new ones. Alfredo in particular has a really good one: how will the alternatives affect Select Sprocket's relationships with third-party service providers? Olivia with help from the others, explores these effects in the simulations, extends the summary to answer the questions, and pretty soon she's done.

As soon as the discussion begins, she realizes, somewhat to her surprise, that Alfredo is very uncomfortable with the proposed changes to this area of family values. As the discussion progresses, the group gradually figures out that he gives a lot more weight than most of them to some of the bad experiences in the European expansion a few years earlier. Of course, he was on the front lines, so they are very interested in taking account of his response. Steven and Lily work with him to restructure the history so he's satisfied that it reflects his experience. The result is rather different from Olivia's original version, but it turns out that most of the alternatives still map into it about as well as before— with the important exception of *Separate Service Products*, which now clearly doesn't fit.

As the group reviews the three remaining draft solutions, they realize that *Service to Fit the Customer* and *Service is the Product* can be merged cleanly into an approach that is definitely the best. They call the new pattern *Appropriate Service*, and spend a little while exploring how it extends the family history that Olivia pulled together— the extension is unexpected, but in retrospect it seems appropriate and even desirable. It provides a new interpretation of *Good Service Makes Strong Relationships* that seems like a significant improvement. Everyone agrees that this is approach is worth pursuing and that the change should be evaluated and implemented if no significant problems show up.

The group delegates the actual evaluation and implementation to Olivia and Alfredo, with review by Evan. They make a little ceremony of the final authorization, as each of them authenticates and invokes their proxies. Olivia is pleased; she's never before participated in an authorization at this level and it definitely gives her a feeling of having been part of something substantial. As the meeting winds up, Olivia checks with Alfredo and they both agree that it's worth trying to get it done by the end of the week. They will be looking over each others' shoulders a lot throughout the implementation, though since it's now pretty late in Belgium, he's not going to be doing much until tomorrow morning. Alfredo signs off, and Olivia chats for a little while with the others in the room, who congratulate her on a clean initial summary and an interesting problem.

Commentary on Collaborative Decision Making

As Herbert Simon explains in his famous parable of the ant [Simon 1969], the complexity of decision making is a joint function of the decision makers and their environment. As the ant's behavior is structured by the complex demands of the land it is traversing, the decision process followed by Olivia and the other Select Sprockets people is organized around the

ongoing complexity of Select Sprockets and its environment, largely encountered through the user interfaces of their digital systems.

In particular, the decision process is largely focused and structured around Olivia's problem summary. Because it is live and ties back to the policies, tools, and massive data of the Select Sprockets systems, participants can use it as a viewpoint to explore the issues themselves, and then as a framework to relate their discoveries to those of other participants. Working groups spontaneously create such frameworks today in the form of new concepts, terms, and rules of thumb; in fact some research indicates that the groups that create the most extensive new frameworks also do the best design [Mabogunje and Leifer 1996]. By providing an infrastructure for this process, Select Sprockets' digital systems help groups quickly create, assimilate, and use such a framework, and thus help the organization reinvent itself as needed.

Today's systems are planned, then implemented, then deployed. In theory, at least, the deployed system is what the designers and implementers define it to be. This can only work if the designers can get it right in their planning, and if it is still right when it is deployed. Unfortunately these assumptions are a potential source of catastrophic mismatches between rigid systems and the work they are intended to support. Increasingly, however, systems will be grown, not defined; their definition will emerge not in planning, but in use; design, implementation and deployment will be on-going, locally initiated, and made coherent through synthesis managed by those involved, not by designers standing somehow "outside" the work itself. This shift is already noticeable in open-source systems and in digital systems largely built from software components, scripting, and layout (like many web environments).

The ability of new participants to propose new solutions (e.g. Lily's contribution), for new structure to emerge in discussion (e.g. Evan and Olivia's discovery of the two-axis organization), and for synthesis to lead to stronger solutions (e.g. the merging of the two leading solutions) depends on having a shared framework, but also having the ability to modify and extend it on the fly. If the participants were locked into a simplistic, rigid framework, like today's database schemas, it would be fatal to this process. If the framework was supported by digital technology but was merely passive, like today's presentations and memos, it would not provide the integration with Select Sprockets' real environment needed to make this process feasible.

In spite of the importance of digital support, we do not believe that digital systems could autonomously generate "optimal solutions" or otherwise lift the burden of the decision process from the shoulders of people in the organization. All of the examples above required human creativity. Furthermore, people will often have key experiences that are not captured by the digital system— for example, Alfredo's direct knowledge of the European expansion— which can play an essential role in guiding the process.

In real decision processes, the interesting action is not the "decision"— a choice between alternatives— but the synthesis of alternatives and the framework for evaluating them. In our example, the process of evaluation and synthesis continues down to the end, and the choice becomes easy, since the process has produced a clear winner (though that will not always be the case).

Synthesis plays a crucial role in maintaining coherence across the organization. Initially, the participants in the decision process may have very different perspectives and may not even be able to understand each other's concerns or proposals. Their mutual effort to assimilate and reflect each others' responses must eventually lead to compatible (though not necessarily equivalent) perspectives to let them collaborate smoothly. The digital portions of these

perspectives allow their users to translate effectively between otherwise incommensurable domains.

In any real decision process, the participants must work with many background constraints; in our scenario, the most obvious one is the MegaMedia family policy *Good Service Makes Strong Relationships*. In the scenario, Select Sprockets neither simply complies with this constraint nor abrogates it; instead, the participants find a creative way to build on the existing history around *Good Service Makes Strong Relationships* to open up a new path for Select Sprockets (and as we will see below, for other organizations). The digital infrastructure must be flexible enough to allow them to relate their new solution to the existing policy, and to help them evaluate and propagate their reinterpretation of the policy.

The history that Olivia has pulled together and brought into the decision process, and that is revised in the final synthesis and evaluation of the solution, plays a key role in enabling the creative response to this external constraint. A simple statement of a policy is both too rigid and too vague— it fails to indicate the ways in which it can be reinterpreted, and it fails to show how to apply it to specific cases. The history of the ways various organizations have used a policy is much richer and more suggestive, though also very likely somewhat inconsistent and difficult to interpret. The process of collecting, interpreting, and using this history must be supported by the digital systems that hold it, so these systems must be capable of handling inconsistent, ambiguous material— in other words, rich semantics.

Finally, all of this flexibility must be controlled. Changes with potentially major impact on an organization must not be made casually, or without accountability. Olivia has assembled people with the necessary authority (held through their proxies), but this is a sufficiently important decision that they still must explicitly authorize the changes that they have collectively agreed to. On the digital side this may simply be another specific move, albeit one with more than the usual protection attached to it, but on the human side, something of this importance naturally tends to develop a particular social meaning and a bit of ritual.

Olivia Helps to Implement a Change

Olivia heads to her favorite office to begin working on the implementation of the change. Working at home would be more convenient, but she wants to make as much progress by the end of the day as possible, and the office interface is significantly more immersive. She sends a message to the Heavy Metal team letting them know that the meeting was a success, and referencing the new policy, so that they can start thinking about how to work with it. Then she starts to look at the implementation effort. It will be a push to get it done by the end of the day on Friday, but it will be nice to have it out of the way by the weekend.

Olivia makes sure her work is recorded in the Metal Bending thread she set up earlier. Then checks the draft *Appropriate Service Level* pattern for completeness, integrity, and fit to the Select Sprockets environment, fixing problems as she finds them. She explores the ways that this change will affect Select Sprockets business processes, using various simulations, and sends messages to co-workers who can review and moderate the bigger disruptions she identifies. As she goes, she adds annotations to the thread, largely to help Alfredo who will be starting his effort in a few hours.

By now it is after five and Olivia wraps up, broadcasting a “heads up” message that warns about the likely change and asks for feedback. She directs questions to the people who were at the meeting; given her proxy coverage, everyone should have been represented there. Then she heads home for dinner and some time with Tina. Afterward, she does a bit more work in

her office, but she soon decides that the internal review is essentially complete and everything is ready for Alfredo to review the external impact.

Friday morning, Olivia checks from home and can see that Alfredo's review is mostly complete. As they expected, there will certainly be some disruption— in fact, two contracts with outside suppliers will need to be renegotiated— but Alfredo has concluded that these are mostly for the good; the new pattern seems to be catalyzing improvements. There are also quite a few responses to her messages, some including suggested sub-pattern changes and complementary changes needed in other patterns she did not know about, but none of them indicate serious problems, and several are very supportive.

Together, she and Alfredo integrate the information from their impact reviews and the feedback from others in the organization into a comprehensive analysis of the change. They conclude that the change will almost certainly increase Select Sprockets responsiveness significantly at little or no cost to its coherence. The result should be an opportunity to move into a significantly stronger relationship with a new set of customers. Evan joins them and reviews their efforts; as usual, another point of view helps them get rid of some unnecessary complexity and pushes them to make some assumptions explicit. When they are done, all three of them authenticate themselves and authorize adoption of the change plan, referencing the delegation by the meeting.

The next day, Saturday, Olivia spends a little while checking Select Sprockets status with her tablet. The changed policy won't become the default until the following Monday, so things don't break over the weekend when the people who could fix them aren't around. Still, she can see that some projects have started to shift ground a bit, in response to the new options. Heavy Metal in particular, since they've been involved from the beginning, have aggressively reworked their support plans, and it now looks like they will be able to make some exciting new moves. Happily, no problems crop up over the weekend, though Olivia checks a few times and does a bit of further cleanup on Sunday afternoon.

Over the next week, she gets a lot of messages, mostly questions and a few complaints. There are three or four serious issues, which she helps to resolve. In two cases she has to get the complainers to talk to their representatives in the meeting; she's glad she got a strong set of proxies. She knows this is mild; she remembers the crisis over the associate privileges issue which almost led to an organizational split. As questions are answered and issues are resolved, she extends the change description to reflect the evolving interpretation of the decision.

She can see work proceeding as the various projects respond to the top-level change. Two of the projects (including the Grinders, oddly enough) have opted to stay with the old policies for the time being, because they're in time critical phases of their release cycle and they can't afford the disruption. The other projects are shifting their policies incrementally, but it will obviously be weeks before they are done, except for Heavy Metal, which is operating completely in the new framework.

Olivia also notices some response to the changes by other organizations. Select Sprockets has started to renegotiate some of its contracts, and that has prompted the other organizations involved to look at the new policies. Also, another member of the MegaMedia family has been having a problem similar to the Heavy Metal project, and they have heard about the change as well through their friends in Heavy Metal.

For the next several weeks, Olivia tracks the changes and monitors Select Sprockets' responsiveness and coherence, maintaining registration between the actual events and the simulation that's part of the change description. She's happy to see that the coherence stays

high, even with occasional disruptions, as the changes percolate through the organization. Responsiveness is harder to measure short term, but after a few weeks some projects have clearly gained responsiveness and none is worse off.

Six months later, Olivia is working with Evan on some policy analysis for a joint project of several of the MegaMedia family members, and they get interested in how the changes played out across the various organizations related to Select Sprockets. They put together a quick tool to trace the propagation of patterns similar to *Appropriate Service Level* across the groups. This is challenging because the definition of similarity has to take into account the distinctive styles of the different groups, but Evan has a knack for this sort of analysis— he is remarkably good at creating patterns that can summarize the style of a collection of other patterns. Using the summaries they can adjust the similarity metrics for each group. They find that the new pattern has propagated to most of the MegaMedia organizations similar to theirs, and also apparently to a number of their competitors in other families.

Digging out her old summary of the history of *Good Service Makes Strong Relationships*, Olivia ties it into Evan's similarity measures. They can see that their change to *Appropriate Service Level* was part of a movement that was somewhat larger and in a somewhat different direction than they had anticipated. The effect has been a significant shift in the meaning of *Good Service Makes Strong Relationships* and a couple of related family values across most of the MegaMedia family. The overall effect on customer satisfaction and brand loyalty has clearly been positive; coherence between MegaMedia organizations and their customers has increased significantly. On the other hand, Select Sprockets has had to make additional adjustments to its own market posture as a result of the continuing changes. Evan thinks that such a rapid and substantial shift indicates that the family is moving along a new gradient in strategy space and that they should try to characterize it in more detail soon. Olivia is willing to take his word for it; strategy space is a bit too technical for her. In any case, they agree that it's beyond the scope that they should be considering for the joint project, and set it aside for the moment.

Commentary on Making and Propagating Changes

In the final phase of Olivia's story, we see many of the same themes, as they play out in a larger community. Her work ripples out through Select Sprockets and beyond, contributing to a cascade of changes far beyond those we can see.

Olivia's analysis of the change is intertwined with the social structure of Select Sprockets. As she explores the implications, she needs to find the potentially affected parties, and tell them how they may be affected. By involving people whose activities fit the new policy pattern, Olivia can recruit them to explore and prepare for its implications. Like Olivia, they will engage the new pattern by looking at its history, by looking inside it to see its details, by trying it out in simulations and by seeing its effects on their own work. So the people she recruits will play an essential role in integrating the change into Select Sprockets' ongoing activities. The "official" review and authorization were a key hurdle, but recruiting and gaining the approval of all the concerned parties within Select Sprockets is a necessary further phase.

With all the flexibility of the digital environment, it is tempting to imagine being able to easily back out of a change if unpleasant surprises show up. However, once a change is "live", many aspects of the system will be affected by it, and simply undoing it quickly becomes impossible. For example, thousands of transactions take place at a busy websites in a few minutes; if a new service policy is offered for even a few minutes, the company may be honoring that policy for years, and thus the policy itself must be kept around for years. So if a change has problems (as

it almost inevitably will), the problems have to be addressed through further (but hopefully smaller) compensating changes.

Given the wide range of people and activities affected by this kind of change, and the very different time-scales on which these people and activities adapt, graceful support for multiple "realities" within Select Sprockets is essential. Multiple different policies must be able to coexist more or less comfortably. This has ramifications far beyond simply providing some kind of versioning mechanism. Different policies will have different ontologies, will imply different accounting mechanisms, will interpret information in different ways, etc. The need to change and upgrade policies locally within Select Sprockets requires a radically different kind of system architecture from anything we have available today.

This ability of groups to adapt their policies incrementally means that organizational learning can take place as the policy is adopted, and the policy itself can evolve in the adoption process. In fact, social learning and system changes are no longer separate in organizations with this level of digital mediation— they are so interdependent that they are essentially one process.

From this point of view, the role of the participants in Olivia's meeting is ongoing; the decision to adopt the new policy was only the beginning of their participation. The complete rationale for the decision can never be captured in the digital record, and even if it could, the digital record by itself does not produce social change. As proxy holders, the participants in the meeting are accountable to their constituencies. When they made the decision, they knew that they would be on the line to explain and support it to those who gave them proxies. Thus, the proxy system is an explicit mechanism for managing discourse and social learning regarding large-scale changes.

Throughout, understanding and communication about the changes depend on a *lingua franca* that bridges the social and digital worlds— in this case, patterns. The availability of this *lingua franca* lets everyone use the digitally mediated history of the change as a context for the many others throughout Select Sprockets and beyond who must deal with the change. The history of this change also becomes part of the larger history of the original family pattern, *Good Service Makes Strong Relationships*— just the sort of history that Olivia searched in her original investigation. In turn, the history Olivia has recorded will be enriched by others with information on the difficulties that emerge during implementation and how they are resolved.

This change is also a part of a larger, less explicit decision process. Even though the decision makers at Olivia's meeting only have authority with respect to Select Sprockets, other organizations will notice their choice and its results. That in turn will contribute to their own decisions. The availability of a rich history of the change will give this larger decision process greater depth and effectiveness— as we have already seen in the use of prior history to help make this decision.

Finally, the socio-technical learning process is reflexive throughout; it is continually monitoring and controlling the process itself, at many different levels. The simulations used to analyze proposed changes need to take account of the process of change itself. Olivia monitors the responsiveness and coherence of Select Sprockets, to see if the change is working. Evan and Olivia measure and analyze the changes underway, as they play out over many organizations, and build models of the change process, which indirectly include their own modeling activity. In general, each entity, at each level, must monitor its own learning process; it must be at least minimally "self-aware".

Conclusion

This essay has been able to discuss only the tip of an enormous iceberg of issues related to making digital systems more supportive of human interaction in a broad sense. Much more remains to be said about the technologies required (and rapidly becoming available) to enable such systems; the research needed to create them; the social forces that oppose and encourage them; and the almost unexplored social and personal opportunities they open up.

However, in this paper our goal has been simply to give our readers some feeling for the possibility that systems in the new millennium will not be incremental extensions of the systems we know today, but perhaps radically different, with radical implications for individuals, organizations, and society as a whole.

This perspective on the possible future of human computer interaction has many implications for HCI designers, but in conclusion, we want to reiterate only the broadest and most crucial point: remember that digital systems do not have to be, and ultimately cannot be, rigid, consistent, and thin. The disciplines that surround HCI— computer science, experimental psychology, organizational theory— will continue to drive design in this direction, to the detriment of users, systems, and organizations. However, as digital systems become increasingly constitutive of our social fabric, HCI will increasingly have the potential to open up this unexplored territory, and to redefine the experience of computing. Let us seize that opportunity.

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