COMMUNICATIONS of the ACM

JUNE 2008 VOLUME 51, NUMBER 6

INFORMATION ACCOUNTABILITY

RISKS OF NEGLECTING INFRASTRUCTURE

BRAP FORENSICS

ORGANIC USER INTERFACES

Designing computers to take on any shape or form

Association for Computing Machinery

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Associazione Italiana per l'Informatica ed il Calcolo Automatico

20° EDITION

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Milano

20TH WORLD COMPUTER CONGRESS

Milano (Italy), September 7-10, 2008

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The AICA' 46th National Congress

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- Biologically Inspired Cooperative Computing - BICC [TC10]
- Distributed and Parallel Embedded Systems - DPES [WG10.2]
- 1st IFIP Entertainment Computing Symposium - ECS [TC14]
- Learning to live in the knowledge Societies - ED_L2L [TC3]
- History of Computing and Education - HCE3 [TC9, WG9.7, TC3]
- Human Computer Interaction - HCI [TC13]
- IFIP Artificial Intelligence 2008 -IFIP AI [TC12]
- 23rd IFIP International Information Security Conference - IFIP SEC [TC11]
- Advances in Information Systems Research, Education, and Practice - ISREP [TC8]
- Knowledge Management in Action - KMIA [WG12.6]
- Open Source Systems 2008 - OSS [TC2, WG2.13]
- 5th IFIP International Conference on Theoretical Computer Science - TCS [TC1]
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Industry Conferences:

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- ICT for Cultural Heritage
- Service Science
- e-Government
- ICT Professionalism & Competences
- e-Inclusion
- ICT for Health
- Web 2.0
- ICT for Education
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Noteworthy Computer Science Journals

International Journal of Computer Vision

Co-Editors-in-Chief:
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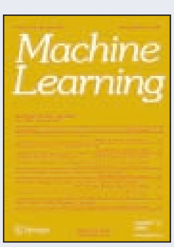
International Journal of Computer Vision (IJCV) details the science and engineering of this rapidly growing field. Regular articles present major technical advances of broad general interest. Short articles provide a fast publication path for novel research results. Survey articles offer critical reviews of the state of the art and/or tutorial presentations of pertinent topics. The journal also features book reviews, position papers, editorials by leading scientific figures, as well as additional on-line material, such as still images, video sequences, data sets, and software

ISSN 0920-5691 (print version)
ISSN 1573-1405 (electronic version)
Journal no. 11263



Machine Learning

Editor-in-Chief:
Foster Provost

Machine Learning is an international forum for research on computational approaches to learning. The journal publishes articles reporting substantive results on a wide range of learning methods applied to a variety of learning problems. If features papers that describe research on problems and methods, applications research, and issues of research methodology. Papers making claims about learning problems or methods provide solid support via empirical studies, theoretical analysis, or comparison to psychological phenomena. Applications papers show how to apply learning methods to solve important applications problems. Research methodology papers improve how machine learning research is conducted.

ISSN 0885-6125 (print version)
ISSN 1573-0565 (electronic version)
Journal no. 10994

International Journal of Parallel Programming

Co-Editors: **U. Banerjee**; **N. Carriero**; **A. Nicolau**

International Journal of Parallel Programming is a forum for the publication of peer-reviewed, high-quality original papers in the computer and information sciences, focusing specifically on programming aspects of parallel computing systems. Such systems are characterized by the coexistence over time of multiple coordinated activities. The journal publishes both original research and survey papers.

Fields of interest include
► linguistic foundations, conceptual frameworks, high-level languages, evaluation methods, implementation techniques, programming support systems, pragmatic considerations, architectural characteristics, software engineering aspects, advances in parallel algorithms, performance studies, and application studies.

ISSN 0885-7458 (print version)
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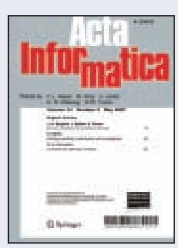


Acta Informatica

Editor-in-Chief:
Ernst-Rüdiger Olderog

The journal provides international dissemination of contributions on the art, discipline and science of informatics. Its scope covers design, description, presentation and analysis of programs, information structures, computing systems and interaction between components thereof.

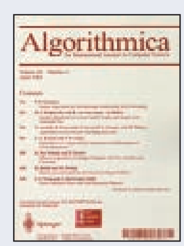
ISSN 0001-5903 (print version)
ISSN 1432-0525 (electronic version)
Journal no. 00236

Designs, Codes and Cryptography

An International Journal

There is a great deal of activity in design theory, coding theory and cryptography and recently there has been considerable research done which brings together more than one of the subjects. **Designs, Codes and Cryptography** provides a forum for high quality papers of both a theoretical and a practical nature which bridge more than one of these areas, encouraging interaction between them. It emphasizes the algebraic and geometric aspects of design theory, coding theory and cryptography.

ISSN 0925-1022 (print version)
ISSN 1573-7586 (electronic version)
Journal no. 10623



Algorithmica

Editor-in-Chief:
Ming-Yang Kao

Algorithmica is an international journal which publishes theoretical papers on algorithms that address problems arising in practical areas, and experimental papers of general appeal for practical importance or techniques. The development of algorithms is an integral part of computer science. The increasing complexity and scope of computer applications makes the design of efficient algorithms essential. **Algorithmica** covers algorithms in applied areas such as: VLSI, distributed computing, parallel processing, automated design, robotics, graphics, data base design, software tools, as well as algorithms in fundamental areas such as sorting, searching, data structures, computational geometry, and linear programming.

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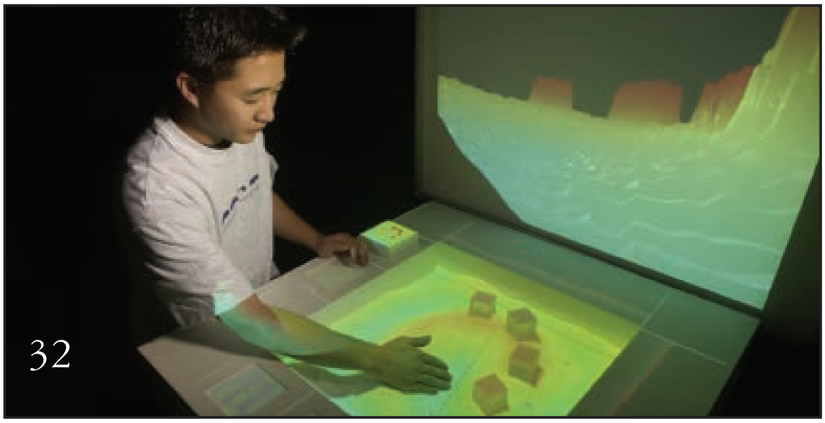

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Editorial Pointers

WITH THIS ISSUE, WE CLOSE ONE CHAPTER IN THE evolving history of *Communications* and prepare to write another. Indeed, it is only fitting that a publication dedicated to chronicling how science and technology change our world take a look within to assess how best to recharge the editorial direction driven by those changes.

The editorial mix in this issue certainly befits the *Communications* legacy. We begin with a stunning collection of stories and images that tell of a (near) future where computing takes any shape or form—displays that bend and fold, that start as one shape but change with user needs—courtesy of the emerging field of Organic User Interfaces. There is also a pronouncement from a stellar group of Web industry leaders who argue that personal accountability must be a strong component of great technological work. And interspersed throughout the issue are accounts of real-world applications and practices that serve to teach, explore, and spark discussion.

The July issue will unveil a new editorial model and striking new look. Editor-in-chief Moshe Vardi gave us an early peek at this model in the January 2008 issue (http://mags.acm.org/communications/200801/). Former ACM President David Patterson explains the process and factors that inspired the redesign in a Webcast available at http://www.acm.org/news/featured/cacm-redesign/. And if you are interested in exploring editorial opportunities, please see the new Author Guidelines on page 105.

Words will never convey the gratitude and appreciation for all who have served *Communications* and its readers for the past 15 years. The next editorial vision finds roots in the tireless efforts of our Editorial Advisory Board, as well as the authors, columnists, and reviewers always striving to maintain the editorial quality *Communications* readers demand. And words can never capture how this editorial staff continues to produce top-quality issues each month, besting comparable publications with four times the headcount.

To Art Director Caren Rosenblatt, who leaves us with this issue, words are no match for her deft talent in welcoming a reader into a story with elegant imagery. This issue clearly reflects the graphic gift she brought to the table every month for 12 years. It is a testament to her ability that under her guidance, a dozen illustrations appearing in *Communications* over the past year alone have won top honors in the graphic arts industry—beating out the biggest commercial magazines in the publishing world. Caren, our resident world traveler, has a world of opportunity to explore. Whatever path she chooses, I know she will do so with the same passion and colorful flair we've come to count on and admire.

Diane Crawford

EDITOR

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News Track

Flash in the Pan

Researchers at IBM Almaden Research Center have demonstrated the feasibility of a class of data storage called racetrack memory that combines the data storage of a magnetic hard disk with the speed and strength of flash memory at relatively low cost. *Technology Review* reports that, unlike flash, racetrack memory would not degrade over time. A recent *Science* article depicted racetrack memory as an array of billions of nanowires on silicon. Each nanowire is able to hold hundreds of bits of data, encoded by changing the magnetic properties along the wire, thus creating a series of magnetic barriers called domain walls. In order to move the domain wall down the nanowire, the team uses principles from spintronics, injecting a small electrical current into the nanowire, causing the electrons in the current to become polarized so their spins are uniformly oriented, handing off the changes to the atoms in the wall. Team leader Stuart Parkin calls the effort a milestone in developing a prototype. While still in the early stages of research, racetrack memory is seen as an attractive replacement for both hard disks and flash memory, leading to smaller computers and extremely inexpensive memory for iPods and other portable devices that now rely on flash memory.

iPods Packing

Researchers at Glasgow University in Scotland also claim a storage breakthrough that could see memory capacity of mobile devices like iPods increase astronomically. BBC News reports Lee Cronin and Malcolm Kadodwala, from the university's chemistry department, have developed a molecule-size switch that could boost data storage without having to increase the size of the devices. The biggest iPod player today holds about 40,000 songs. New nanotechnology could theoretically allow users to store millions of video and music tracks. Indeed, the work could see 500,000GB squeezed onto a microchip. The microscopic switch—consisting of two clusters of molecules positioned just 32 millionths of a millimeter apart—allows scientists to easily manipulate an electrical field. By placing these switches on a gold or carbon surface, they could fit up to one billion transistors on a single chip. The technology could also be used in other electrical devices, such as DVD players, to increase memory and performance. Says Cronin: "The fact that these switches work on carbon means they could be embedded in plastic chips so silicon is not needed and the system becomes more flexible both physically and technologically."

Athletic Harmony

A high-tech armband is helping athletes find their rhythm on the court by playing a special tune when they move their arms correctly. *Technology Review* reports that researchers at the Commonwealth Science and Industrial Research Organization in Victoria, Australia, developed the device as a training tool to improve a player's skills. The "interactive throwing sleeve" includes two sensors at the wrist and elbow connected by thin conductive fibers. As the athlete shoots the ball the sleeve measures the position, velocity, and acceleration of the arm, then wirelessly transmits the data to a laptop for monitoring. Once the system is programmed correctly the armband tracks the player's movements and plays the corresponding tones. The more the player uses the device the more he or she will begin to recognize the pattern of tones associated with a successful shot. The Australian Institute of Sport is working with the researchers to test the device on elite netball players (a sport similar to basketball and popular in the Caribbean, U.K., Australia, and elsewhere).

Photo: Jeremy Levy

News Track

10 Weirdest Computers

New Scientist **notes today's computers use pulses of electricity and flipping magnets to manipulate and store data, but information can be processed in many other—and weirder—ways:**

1. **Optical computing uses light signals to process data and carry out computations.**
2. **Quantum computing uses quantum mechanical effects to create qubits to run parallel computations.**
3. **DNA computing processes data and runs programs stored in sequences of genomic base pairs.**
4. **Reversible computing aims to recover and reuse energy typically discarded in computational operations.**
5. **Billiard Ball computing uses logic circuits that employ cascades of atoms bouncing off each other.**
6. **Neuronal computing copies nature's very own computer—the brain.**
7. **Magnetic computing uses strong magnetic fields to control and observe the way molecules interact.**
8. **Glooper computers favor gloopware rather than hardware to make waves of propagating ions in a chemical goo behave like logic gates.**
9. **Moldy computers emulate how slime mold works out the shortest route through a maze.**
10. **Water wave computing uses wave patterns to make a type of logic gate.**

Hooking Big Phish

An email scam targeting top executives in the U.S. is raising new alarms about the ease with which people and companies can be deceived by online criminals. The *New York Times* reports thousands of high-ranking executives received email messages that appear to be official subpoenas from the U.S. District Court in San Diego, CA. Each message included the executive's name, company, and phone number, and commanded the recipient to appear before a grand jury in a civil case. A link embedded in the message purported to offer a copy of the entire subpoena, but any recipient opening the document would unwittingly download and install software that secretly recorded keystrokes and send the data to a remote computer allowing the criminals to capture passwords and other personal or corporate information. Another piece of software allowed the computer to be controlled remotely. According to researchers who have downloaded the file, less than 40% of commercial antivirus programs were able to recognize and intercept the attack. Security analysts contend the tactic of aiming at the rich and powerful with an online scam, called whaling (a play on phishing, as in big phish), is one they expect to see grow with disturbing results. The real danger, they say, is in the second level of deception, where digital credentials may be gleaned without the recipient's knowledge. At press time, researchers examining the scam message claimed it probably originated in China. "If all the key players are in China," said one security expert, "there is not much the FBI can do."

Robotic Infusion

Robots could fill the jobs of 3.5 million people in graying Japan by 2025, helping avert worker shortages as the country's population shrinks. Japan faces a 16% reduction in the size of its work force by 2030, while the number of elderly increases greatly, according to government estimates. This scenario raises concerns about who will do the work in a country unaccustomed to, and to date unwilling to, consider large-scale immigration. The Machine Industry Memorial Foundation, a Japanese think tank, says robots ranging from micro-size capsules that detect lesions to high-tech vacuum cleaners can help fill the gaps. Rather than expecting each robot to replace one person, the foundation says robots could make time for people to focus on more important things. Japan could save about 2.1 trillion yen ($21 billion) of elderly insurance payments in 2025 by using robots that monitor the health of older people so they do not need to rely on human nursing care. Robotic devices can also alleviate housework and some childcare responsibilities. C

Send items of interest to cacm@acm.org

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FORUM

Money Alone Not Enough to Motivate Data Theft

The theft scenario explored in "The Illusion of Security" (Mar. 2008) by David Wright et al. was realistic, with one exception, though it didn't detract from the article's conclusions. Wright et al. wrote: "A third driver, not so dissimilar from the first, is that the data thieves are also impelled by the profit motive." The thieves in this case were employees who disappeared one day and some time later turned up in Costa Rica.

I realize the scenario was abbreviated, with many details omitted, but after having interviewed more than 200 computer criminals in my own studies (see *Crime by Computer,* Scribners, 1976, and *Fighting Computer Crime,* Scribners, 1983), I conclude that few computer criminals are indeed motivated purely by profit. Employees become criminals during employment mostly to solve personal problems that may involve money, sabotage, or espionage. They are often motivated by debt, relationships gone bad with other employees or spouses, personal dissatisfaction, or an attempt to hide poor or unethical business decisions. If the thieves cited in the article were motivated by profit alone, staying with the company and surreptitiously selling its products and services under the table and engaging in accounts-receivable or -payable fraud, their behavior would likely be less dangerous and obviate the need to flee. On the other hand, they may have been in touch from the start with a buyer interested in the whole database who initiated the theft. However, I have found that collusion between two perpetrators is rare and among three rarer still when IT is involved. It usually takes only a single person with the proper skills, knowledge, resources, authority, motives, and objectives.

DONN B. PARKER
Los Altos, CA

COLLABORATIVE SOLUTIONS FOR DISPARATE PROBLEMS

Peter Denning's and Peter Yaholkovsky's "The Profession of IT" column "Getting to 'We'" (Apr. 2008) was especially interesting in terms of open-source development. Although both authority and competition have a place in vibrant open-source communities, it is surprising how often collaborative solutions satisfy disparate needs. For example, both SMP scalability and real-time response are sometimes improved by changing the kernel's synchronization design.

I cannot say whether the five stages of collaboration outlined in the column apply directly to open source but attest to the effectiveness of the third stage: "listen to and learn all perspectives." I'm intrigued by how "declare" and "connect" might by undertaken by a new generation that has grown up with the Internet.

PAUL E. MCKENNEY
Beaverton, OR

DISK INCREASES SIZE OF MEMORY-LIMITED SEARCHES

I agree wholeheartedly with Daniel Kunkle's and Gene Cooperman's "Viewpoint" "Solving Rubik's Cube: Disk Is the New RAM" (Apr. 2008). In fact, my co-authors and I have been developing disk-based search algorithms and using them to solve combinatorial problems since 2002. For example, the well-known Towers of Hanoi problem

PAUL WATSON

is more than 125 years old. But with four or more pegs, the optimal solution length is not known in general. Using more than 2TB of disk space, we've completed breadth-first searches of the four-peg Towers of Hanoi problem with up to 22 discs, a problem with almost 17.6 trillion states. We've also performed disk-based heuristic searches of the problem, confirming a 1941 conjecture due to J.S. Frame and B.M. Stewart about the optimal solutions to these problems for up to 31 discs.

As another example, the sliding-tile Fifteen Puzzle was by many accounts as famous in the 1880s as Rubik's Cube in the 1980s, as documented by Jerry Slocum and Dic Sonneveld in their book *The 15 Puzzle: How It Drove the World Crazy.* In 2005, using 1.5TB of disk space, we completed a breadth-first search of the 4x4 Fifteen Puzzle, with more than 10 trillion states. This verified a result due to Adrian Brungger et al. that the most difficult problem instances take 80 moves to solve. We then found that the most difficult instance of the 2x8 Fifteen Puzzle takes 140 moves to solve.

More recently, we considered the pancake problem whose only claim to fame is that it is the subject of a technical paper co-authored by Bill Gates ("Bounds for Sorting By Prefix Traversal" in 1979). In it, we want to sort a stack of pancakes of different sizes using a spatula that flips over the top K pancakes as a group. In another version of the problem, one side of each pancake is burned; in addition to sorting them by size, we now want all burned sides face down. Using 3TB of disk storage, we found the maximum number of moves needed to solve the 14 and 15 unburned pancake problems and the 11 and 12 burned pancake problems. The 15 unburned pancake problem has more than 1.3 trillion states; the 12 burned pancake problem has almost two trillion states.

In addition to these challenging toy problems, many of these techniques are applicable to real-world problems as well. In particular, most NP-complete problems are combinatorial in nature, and all known methods for solving them optimally involve searching large numbers of states. I agree with Kunkle and Cooperman that the use of magnetic disk can increase the feasible size of memory-limited searches by several orders of magnitude.

RICHARD E. KORF
Los Angeles

Author's Response:
We thank Korf for his complimentary comment. We have long admired his own use of disk-based parallel computation. We look forward to the popularization of the technology and its increased use in real-world problems.

DANIEL KUNKLE
GENE COOPERMAN
Boston

NO ROOM FOR WEAK LINKS IN SECURITY IN DEPTH

Hal Berghel's "Digital Village" column (Apr. 2008) "Faith-Based Security" made valid points and it's title was somewhat provocative, but I take issue with its treatment of "security in depth." SID has a simple definition: create a path of multiple sequential steps where the sum of the least cost-path represents the optimal effort an attacker would have to expend to achieve the target (nefarious) effect.

The key words are "sequential" and "sum." In terms of simple graph theory, SID forces the attacker to traverse multiple nodes representing independent compromises at cumulative cost across all edges (such as in two-factor authentication). In contrast, a "chain link" defense is only as strong as its weakest link because the attack takes place simultaneously on all nodes, so the compromise of any one of them compromises the entire defense (such as in port scanning). In the case of a physical chain, straining the chain simultaneously places sheering load where each link joins its neighbor. Once the chain breaks anywhere its ability to restrain is gone.

Amazing to me is how many security professionals and managers do not understand the fundamental difference between SID and the chain-link style of protection. Worse, they may think they have a SID architecture when in fact they have only a chain link.

ROBERT J. DUWORS
Bellevue, WA

FORGET WEP; GIVE ME WPA ENCRYPTION

The discussion and advice in Alfred Loo's "The Myths and Truths of Wireless Security" (Feb. 2008) did nothing to dispel the myths, even as it introduced some advice that should not have been included. For example, being told that "Users should turn on the encryption feature in the router" was misleading, as it indicates that any form of encryption will do. However, the encryption method known as Wired Equivalent Privacy, or WEP, is "worse than useless" (www.securityfocus.com/infocus/1824) and "notoriously flawed" (www.mobile-tech-today.com/perl/story/22207.html). Roberto C. Sanchez said it beautifully: "WEP is the equivalent of leaving the bank vault open at night with a sign saying 'Please stay out'" (unixadmintalk.com/f11/wep-encryption-ndiswrapper-103651/). The column's advice should have been: Enable Wi-Fi-Protected Access, or WPA, encryption and don't bother with the rest. No mention was made of fatally flawed encryption methods (it takes seconds to break WEP), indicating, perhaps, that security is beyond the understanding of almost everyone.

There was nothing wrong with the column's list of user responsibilities, but they are like saying one should check the water, oil, and brake-fluid levels before driving a car. This may be reasonable advice but is likely to be ignored. The car analogy did offer some direction by adapting the standard rules: green lights (or no lights) are OK, orange is a warning, and red is a problem. Manufacturers should thus consider adding green, orange, and red lights to their wireless devices. Orange would mean the device settings have been accessed from outside the private network; clearing the changes would require pressing a physical button on the device. Red would mean an important firmware update is available. Although users can't be expected to update their firmware, they should be expected to understand that red means "See a technician."

Berend de Boer
Auckland, New Zealand

HOW TO TEACH PROGRAMMING TO NOVICES

Chenglie Hu's "Viewpoint" "Just Say 'A Class Defines a Data Type'" (Mar. 2008) addressed issues the South African Education Department has been debating over its curriculum for teaching programming and software-development in the country's high schools (grades 10–12).

Under the curriculum, schools can choose between two programming languages: Java and Delphi. However, the pro-Java and pro-Delphi teachers are divided with regard to object-oriented programming, event-driven programming, use of GUIs, and possible drag-and-drop advantage for Delphi learners. Teaching "objects first" is an approach advocated by most Java teachers and "objects later" an approach advocated by most Delphi teachers. Some Java teachers avoid GUIs and IDEs, preferring a text-based approach. In addition, each side has characterized the other as taking a "procedural approach" rather than an "object-oriented approach."

The two groups are further divided by their views of which language is best for teaching programming to 15-year-olds. Hu suggested the answer lies more in the teaching approach and less in the programming language itself. Many teachers are of the opinion that problem solving should be the focus and that the language is only a tool. However, when teaching how to use that tool, the focus might be more on learning how to use the language than on solving problems. In any case, students must be prepared to answer whether a particular tool should determine the strategy for solving a particular problem.

Should we educators follow Hu's approach, exposing students to problem-solving paradigms and strategies and preparing them to be able to choose the most appropriate tool (language and/or data structure) to solve the problem at hand? Our decision to remove data representation from the curriculum could turn out to be a mistake if Hu's view that the study of data types and how data is represented is fundamentally important to learning and teaching programming, unless our teachers make sure to fill in this background knowledge.

Our teachers are also pondering other questions in the context of teaching computer programming to novices: For example, What is the proper role of computing algorithms (such as for sorting), when programmers are able to call a method (someone else has written, like .sort) without understanding how a sorting algorithm works? The students must still know the reasoning behind method calls, as well as the proper role of array data types when databases are used as a data structure.

Carina Labuscagne
Pretoria, South Africa

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BRAP Forensics

Boutique computer activity mining vs. personal privacy management.

BRAP forensics is one of the latest additions to the digital forensics toolset.[1] One of the more subtle forms of computer activity mining, it has considerable potential for privacy abuse. Some practitioners distinguish browser forensics from applications footprinting, but the two investigative procedures are so closely related (browsers are, after all, applications) that subsuming them both under the same category of computer activity mining seems more reasonable.

Computer activity mining (CAM) involves the recovery of information about a computer user, or a computer's use, from the computer itself. As such, it is one of the core areas of modern digital forensics along with log analysis, timeline analysis, keystroke capture and analysis, system imaging, and so forth. Log analysis is perhaps the best-known example as it has been a staple of network forensics for years, and is a primary tool for network administrators to reverse engineer hacks of their systems. It is so common in fact that sophisticated hackers consider log cleansing the final stage of a successful hack.

Another core area of digital forensics is media analysis (aka file system forensics)—the practice of recovering data from non-volatile storage devices. Where CAM focuses on activity, media analysis focuses on data. BRAP forensics bridges the gap by revealing stored data as well as information about user behavior. That's what makes it interesting—and threatening to those concerned with personal privacy management.

PETER HOEY

In addition, the courts have made computer activity mining an important area of electronic discovery. Law enforcement officials routinely look to CAM for evidence of wrongdoing. This is particularly true in the prosecution of cases involving unacceptable computer use, sexual harassment, child pornography, EULA, computer fraud, identity theft, and intellectual property cases. As with media analysis, BRAP forensics should be thought of as indiscriminate. Once the warrant is served and the forensics completed, personal privacy issues are no longer applicable.

BROWSER RESIDUE

While the browsing experience is familiar to most computer users, the nuances remain nebulous. These nuances are the grist for the BRAP forensics mill. Internet Explorer (IE) on Windows is noteworthy in this regard because it leaves behind a surplus of browser residue. I will focus on IE, though examples may be derived from non-Windows operating systems and alternative browsers.

The browser is the navigation and rendering tool for the Web. When the user clicks on an icon or

[1] I use the acronym BRAP for BRowser and APplications.

Figure 1a. Example WebTrends cookie.

```
SITE: m.webtrends.com/
VARIABLE: ACOOKIE
VALUE:
    C8ctADEzMS4yMTYuMTE5LjIxLTEwNTUwMjE5NjguMjk5MTU4OTIAAAAAAAAABAA
    AAcAAAAOk5yEeaOchHAQAAABMAAADpOchHmjnIRwAAAAA-
CREATION TIME: 02/29/2008 08:59:30
EXPIRE TIME: 02/26/2018  08:59:21
FLAG FIELD: 2147484672
```

```
SITE: statse.webtrendslive.com/
VARIABLE: ACOOKIE
VALUE:
    C8ctADEzMS4yMTYuMTE5LjIxLTE4ODIyNTE5NjguMjk5MTU4OTIAAAAAAAAABAA
    AA/WAAAO05yEftOchHAQAAAEooAADtOchH7TnIRwAAAAA-
CREATION TIME: 02/29/2008 08:59:34
EXPIRE TIME: 02/26/2018  08:59:25
FLAG FIELD: 2147484672
```

Figure 1b. Example WebTrends cookie.

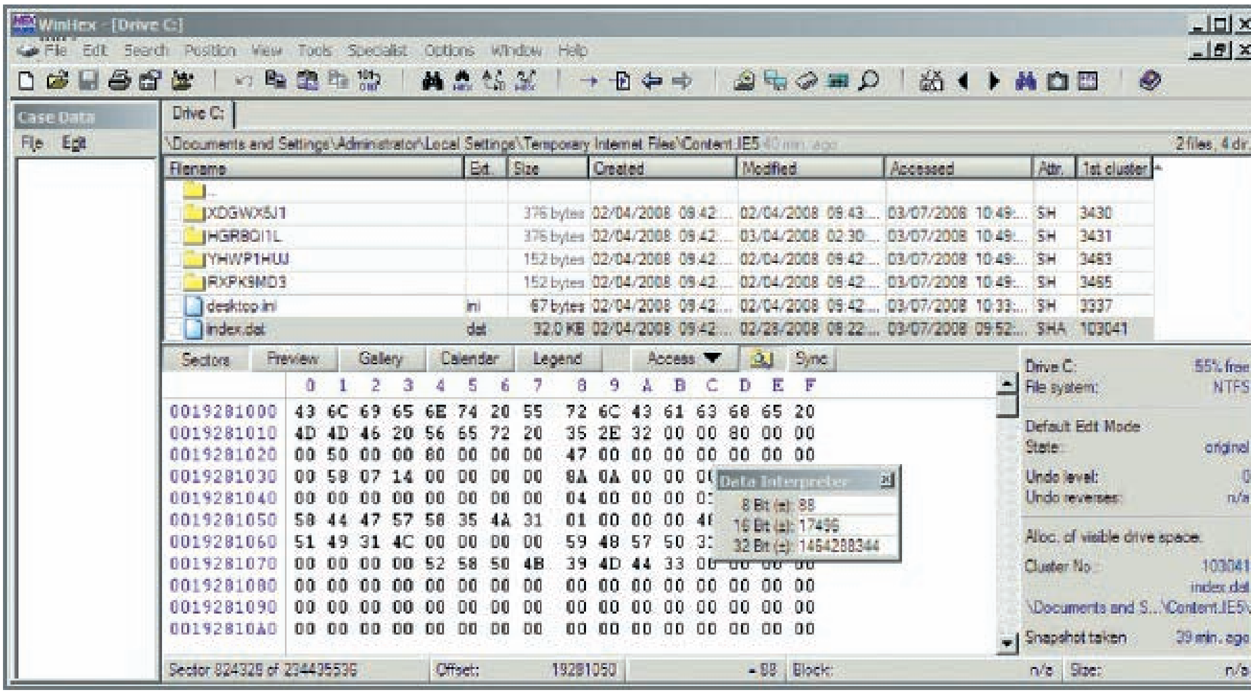
link, the browser sends an HTTP request to a remote resource. That triggers a download of information. There are many by-products of this exchange—some well understood, some less so.

Cookies are one such by-product. Since HTTP is "stateless," the Web development community introduced these identifiers to store information about the client-server exchange for subsequent connections, either during the current browser session (session identifiers) or during subsequent browser sessions (persistent identifiers). Persistent IE identifiers reside in Documents and Settings>(User)> Cookies under the name of the Web site that produced it. For example, when I recently visited the www.microsoft.com Web site, seven cookies from webtrends.com, atdmt.com, indextools.com, and dcstest.wtlive.com were deposited in this folder on my computer. The Webtrends Web site reports that "Influential technology companies such as Microsoft have used WebTrends Marketing Lab 2 to get a real-time view into both online visitor activity and offline customer information," so I have some idea of why the cookie was left.

When parsed, the two webtrends.com cookies appear as shown in Figure 1a and Figure 1b. The precise meaning of the "value" field is irrelevant to the current discussion. The two datapoints of interest are the timestamps—first because the timestamp records when my computer was touched by WebTrends, and second because that record won't expire for 10 years—neither of which leaves me with a particularly good feeling about the experience. As I wrote in a previous column ("Caustic Cookies," April 2001) cookies are transforming our private sanctuaries into electronic auditoriums.

In addition, these cookies collect like lint even if IE security settings are increased. The default browser privacy setting for the risk-averse user might involve putting the privacy setting on HIGH for the Internet zone (IE>Tools>Privacy), because the BLOCK ALL COOKIES setting restricts functionality beyond tolerable levels. The HIGH setting should block tracking cookies and cookies from sites without a compact privacy policy. However, since IE doesn't clear private data on closing (as Firefox does), one must do it manually (IE>Tools>Delete Browsing History>Delete All). Therein lies the rub: the private data is archived in Windows every time the system creates a restore point (XP, 2000) or an incremental shadow copy (Vista). So, if the information isn't manually deleted before that day's backup, it's easy pickings for a BRAP forensicist. System restore points and shadow copies include personal data whether or not you know it. In some cases you can shut them off, but then there's no recovery mode for the operating system. In short, the computer most likely has a record of some or all Web sites visited, and this record is recoverable. The operative question is: Is this what you want?

The same applies to cache and URL history. This data is organized in a largely cryptic INDEX.DAT file in Documents and Settings\<User>\Local Settings\Temporary Internet Files\Content IE5. To illustrate, Figure 2a shows a hex editor's per-



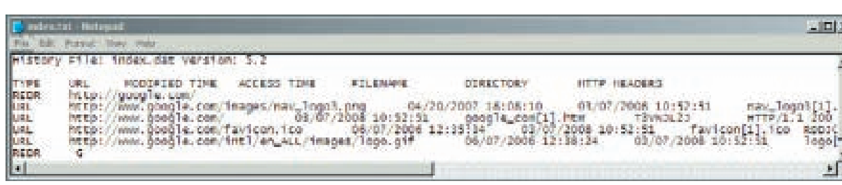


Figure 2a. (top) A hex editor perspective on the INDEX.DAT file and the four cache folders.
Figure 2b. (right) The parsed contents of INDEX.DAT.

spective of INDEX.DAT after a single IE visit to Google.com. Note that the cache filenames are identified in the header of INDEX.DAT. Figure 2b shows the parsed contents of the file. As with cookies, if the user doesn't manually remove all of this data it accumulates in the backup files and is readily accessed. Other tools exist to recover cached images.

LEARNING TO LIVE WITH APPLICATION RESIDUE

Unintended residue is also a byproduct of typical application use, especially with Microsoft productivity tools. I'll illustrate this point with the now-classic example of how Word metadata was used to embarrass Tony Blair's government.

Users become familiar with the Word metadata through the properties box (found under MS Word>File>Properties>Summary). In 2003, Richard Smith extracted the revision log from a 2003 document sent by Tony Blair's government to Colin Powell that was used to justify the attack on Iraq. As it turned out, parts of the document were copied from an article written by a postgraduate student. The source document was easily identified because the copy preserved spelling, grammatical, and typographical transgressions. The metadata in the source document appears in the sidebar here. The metadata of immediate interest are the four abbreviated names in the revision history: phamil, jpratt, ablackshaw, and MKhan, which were usernames of four people in the Blair government. The log reveals three autorecovery backups to the LOCAL\temp directory for userid="cic22," a subsequent copy by jpratt onto a floppy (A drive); another copy made by ablackshaw onto a floppy, and the final editing on Mkhan's computer. According to Smith, Parliamentary hearings

SOURCE DOCUMENT METADATA

```
-------------------
Statistics
-------------------
File = blair.doc
Size = 65024 bytes
Magic = 0xa5ec (Word 8.0)
Version = 193
LangID = English (US)

Document was created on Windows.

Magic Created : MS Word 97
Magic Revised : MS Word 97

-------------------
Last Author(s) Info
-------------------
1 : cic22 : C:\DOCUME~1\phamill\LOCALS~1\Temp\AutoRecovery save of Iraq - security.asd
2 : cic22 : C:\DOCUME~1\phamill\LOCALS~1\Temp\AutoRecovery save of Iraq - security.asd
3 : cic22 : C:\DOCUME~1\phamill\LOCALS~1\Temp\AutoRecovery save of Iraq - security.asd
4 : JPratt : C:\TEMP\Iraq - security.doc
5 : JPratt : A:\Iraq - security.doc
6 : ablackshaw : C:\ABlackshaw\Iraq - security.doc
7 : ablackshaw : C:\ABlackshaw\A;Iraq - security.doc
8 : ablackshaw : A:\Iraq - security.doc
9 : MKhan : C:\TEMP\Iraq - security.doc
10 : MKhan : C:\WINNT\Profiles\mkhan\Desktop\Iraq.doc

-------------------
Summary Information
-------------------
Title  : Iraq- ITS INFRASTRUCTURE OF CONCEALMENT, DECEPTION AND INTIMIDATION
Subject  :
Authress  : default
LastAuth  : MKhan
RevNum  : 4
AppName  : Microsoft Word 8.0
Created  : 03.02.2003, 09:31:00
Last Saved : 03.02.2003, 11:18:00
Last Printed : 30.01.2003, 21:33:00
```

URL PEARLS

Readers interested in more information on media analysis should consult my August 2006 and April 2007 columns. The basic BRAP utilities discussed here were developed by Keith Jones and are an ideal starting point for both BRAP forensicists and voyeurs. These tools are open source and available on the foundstone.com Web site. The reader should be forewarned that the documentation is more difficult to find than the software. Galleta is indispensible in expedient cookie analysis because of the strange cookie data format used by Internet Explorer including, among other oddities, timestamps that are defined in terms of 100 nanosecond increments since midnight, January 1, 1601. INDEX.DAT and INFO2 were parsed by Jones utilities PASCO and RIFIUTI, respectively. The documentation for Keith Jones's tools from which my examples were taken can be located with a search for "Keith Jones" at www.foundstone.com/us/. Mandiant (www.mandiant.com) has a streamlined utility—Web Historian—that saves parsed history data in an Excel spreadsheet for easier analysis. SANS (sans.org) now offers a half-day course in browser forensics. Based on my experience with SANS, I would expect this to be the most thorough treatment available.

The data clusters described here are indexed in the Windows Registry Hive. The most important file in BRAP Forensics is NTUSER.DAT. A good overview of the linkage between the registry hive and critical activity files like NTUSER.DAT is provided in AccessData's Registry Quick Find Chart at www.accessdata.com/media/en_US/print/papers/wp.Registry_Quick_Find_Chart.en_us.pdf.

Perhaps the easiest way to see how the registry hive organizes BRAP data is DeviceLock's Active Registry Monitor (devicelock.com). Registry Monitor has a "compare" feature that reveals differences between registry scans that were produced by applications.

Many of these capabilities are bundled into computer forensics tools such as Encase (guidancesoftware.com), Windows Forensics Toolchest (foolmoon.net/security/wft/index.html), and The Forensics Toolkit (accessdata.com/Products/ftk2test.aspx).

The Tony Blair/Colin Powell case illustrates how effective BRAP forensics may be. For an overview of the plagiarism side of the case, see www.casi.org.uk/discuss/2003/msg00457.html. For the BRAP forensics perspective, see Richard Smith's account at www.computerbytesman.com/privacy/blair.htm. The fragment of metadata appearing in the sidebar was reproduced from the source document at www.computerbytesman.com/privacy/blair.doc by Harlan Carvey's metadata extraction and parsing tool wmd.pl (see cfed-ttf.blogspot.com/2008/01/what-is-your-ms-office-metadata-telling.html). The British government admitted to the plagiarism (www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/2003/02/08/MN200631.DTL). C

revealed that Pratt passed on a floppy disk to Blackshaw who sent it to Colin Powell for his presentation to the United Nations. The revelation of this information, together with the plagiarism, proved to be a credibility disaster for the governments involved.

Consider the millions of email attachments in global circulation daily. How many people actually know about the volume of metadata they are broadcasting?

RECYCLING THAT DOESN'T HELP THE ENVIRONMENT

We all like to think of the delete key as the quintessential digital cleansing experience. But as we know, modern operating systems do not overwrite deleted file data areas but rather just reassign the affected disk space to the operating system for further use. The intermediate step in this process in Windows involves a recycle bin or recycler. But putting digital waste in the recycle bin doesn't destroy anything. In fact it exposes the user to even more risk because the file information is compressed into a smaller part of the disk, which makes recovery easier.

If you think about it, all of the data necessary to recover a deleted file must go in the recycle bin. Otherwise the file couldn't be undeleted. In Windows XP, for example, the information is stored in a file, INFO2. The information

INFO2 File: info2

INDEX	DELETED TIME	DRIVE NUMBER	PATH	SIZE
17	03/07/2008 11:53:50	2	C:\dumpster\Firefox Downloads\AdbeRdr812_en_US.exe	0
0	12/31/1969 16:00:00	0	C	0

Figure 3. Deleted file recovery data.

retained includes path, file size, delete time/date, and unique recycle ID. Of course, one could recover this information with a hex editor, but it's much easier to just parse it, as shown in Figure 3. In this case, I had emptied the recycle bin, sanitized it with Evidence Eliminator, and then deleted an Adobe Reader installer so that it alone is the only contained file. Note that I can recover the location of the file, the time/date deleted, the placement of the file within the recycler, and other information from the data recovered in the recycle bin. Until the recycle bin is emptied, this file is very much readable. But, even if the recycle bin is emptied, only this metadata is lost. The actual file data remains recoverable with a hex editor (unless the clusters have been reallocated to another file—which isn't all that likely on high-capacity drives; see my August 2006 column for additional details).

Another interesting twist is that even if image files are deleted, the recycle bin has been emptied, and the registry and disk have been sanitized, the thumbnails of any image files that remain might still be recoverable if they were ever indexed by Windows Explorer because the image index, THUMBS.DB, stays behind with the folder.

CONCLUSION

It is important that the computer user understand BRAP forensics because of its potential for invasion of privacy. Far from innocuous, browsers and applications software may reveal more of our behavior than we expect. In terms of subtlety, BRAP forensics goes beyond the older, more traditional areas of computer activity mining. Where a computer log provides information that is relatively objective and impersonal, BRAP forensics provides information that is subjective and personal. Think of it this way: knowing that someone logged into a computer and used a word processor is far less invasive than knowing that someone created a document for a specific person, visited a sequence of Web sites, viewed certain image files, saved the document, and then copied it to a USB memory stick with a known unique ID. BRAP forensics drills down to this level of granularity. And the small form factor of today's removable storage media encourages the circulation of personal and private information.

What I find most objectionable is that the production of this data residue is counterintuitive. The bottom line is that this residue exists for the convenience of myopic software developers who believe their vision of computer use is so incontrovertible that there is no need to entertain other points of view, such as those that put a premium on safeguarding personal privacy. How difficult would it be to offer the user complete control over the backup of non-system files and metadata? Or to allow users the option of browsing the Web without recording tracking cookies or URL histories? Or to create a file system where "delete" actually means delete. To the typical user, learning of these developer excesses retroactively is akin to learning that all of the world's typewriters had been secretly producing invisible carbon copies for Interpol. Who would have imagined that anyone ever thought this was a good idea? While hardware-based encryption systems like BitLocker are an improvement, software use of personal information should follow the "need-to-know" paradigm. Encrypting data residue is never as effective as not storing it in the first place. C

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 Robert L. Glass

Software Design and the Monkey's Brain

Attempting to capture the nature of software design.

There has been a lot of brilliant software engineering research over the years and decades into the subject of software design. That's the good news. But then there's the bad news.

The bad news is that all of that brilliant research hasn't enhanced our knowledge of how to do software design in practice. It's like we now have a really good handle on the philosophy of design, and the reality of how to do design well. But that hasn't helped us tell practitioners how to be better designers.

My interest in design, and my belief in the work of software engineering researchers on the subject of design, began over 20 years ago. At that time, Bill Curtis was leading a team of researchers at the former Microelectronics and Computing Consortium (MCC) in Austin, TX, and Elliot Soloway was conducting similar work at Yale University. The goal of these two efforts was to investigate the nature of software design in order to figure out how to do it better. The

MICHAEL SLOAN

expectation, especially from Curtis and his team, was that the result of their investigation was going to be a set of processes—probably tools—that could be provided to software practitioners to help them do their job so much better.

The investigations were very successful. By studying expert designers at work, the researchers learned that the essence of software design was a sophisticated trial-and-error activity:

- Develop a complete understanding of the problem to be solved;
- Build a mental model of a proposed solution to the problem;
  - Mentally execute the model on a sample input to see if it does indeed solve the problem;
  - If the output of the execution is incorrect (as will often be the case in the early stages of design), expand the model to correct the deficiencies, then execute again;
- Once the output of the execution of the model is correct, choose a different sample input and repeat the process; and
- Eventually, the expectation is that a strongly enhanced mental model will be able to solve all of the sample inputs considered.

(To find a more complete discussion of this process and its ramifications, read any of the circa-1980s writings of either

Curtis or Soloway, or see my discussion in my recent book *Software Creativity 2.0* (that discussion is found in the chapter "Creativity and Software Design: The Missing Link").

Now, all of that understanding of design that Curtis and Soloway produced was almost monumental in its scope. We now understood, in very believable ways, that software design as practiced by its experts was a trial-and-error iterative process. This may not have been a terribly acceptable discovery to computer scientists who presumably had hoped for a more algorithmic or prescriptive approach to design, but to software designers in the trenches of practice, it rang a clear and credible bell.

That summarizes the mostly good news I mentioned in the first paragraph of this column. But now here's where the bad news takes over.

As I mentioned, it was the expectation of Curtis and company that, once they learned the true nature of software design from their studies, they would then package some kind of design solution approach (be it process and/or tools) and pass it on to practitioners. In fact, that was the rationale given for the funding that allowed those wonderful research studies to be conducted in the first place. The MCC would be known, throughout the software engineering world, as the place to go for help in solving the problems of software design.

But it didn't work out. Remember that essence of design, the iterative process, I discussed earlier in this column? Well, all of it happened inside the mind, at the speed of human thought. Attempts to enhance the iterative process, such as by jotting down notes or even using computer-based tools, simply slowed the process. The mind could do things much faster than the hand could record its workings, and speed was of the essence in that highly iterative, somewhat complicated process.

I remarked at the time that what we needed was a mind amplifier, a computer-based tool that could record all those wonderful workings of the mind as it went through that iterative process, and convert what it recorded into the results the mind would eventually produce. Big HA! No such tool was available, even in the minds of the artificial intelligence scholars of the day.

My computist-in-training son even envisioned a solution, based on my imaginings, of a mainframe computer on wheels that would be hard-wired into the mind of the designer and would follow him around. Even bigger HA! The idea was as laughable then as it is now.

But wait! A recent issue of ACM TechNews included the headline "scientists use monkey's brain signals to control robot" [1]. The author of that article, and the scientists who had conducted the research, were excited about the prospect of using brain signals to control robots, so that—for example—paralyzed people might be able to use their thoughts to move their bodies.

And that's a hugely laudable application of such a technology. It could be life-enhancing in unimaginable ways to paralytic or severely motor-impaired individuals.

But I couldn't help but think back to the dreams of Curtis and Soloway, and mine, and even my son's, to provide computer support for the software design process. Like so many other wondrous applications of computers over the decades, we may at last be on the verge of finding a way to transfer those design discoveries of Curtis and Soloway into something the practitioner software designer can actually put to use.

I'm not holding my breath, but I find the prospect pretty exciting. Perhaps all that big HA stuff will not be so funny after all. **C**

Reference

1. Gaudin, S. Scientists use monkey's brain signals to control robot. *Computerworld* Careers (online), Jan. 16, 2008; www.computerworld.com/action/article.do?command=view-ArticleBasic&articleid=9057319.

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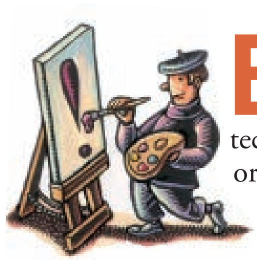
Arik Ragowsky, Paul S. Licker, and David Gefen

Give Me Information, Not Technology

Don't confuse technology with business solutions, focusing instead on what users value most—information.



Business users care about their organizations' information, not about the technology that interconnects or aggregates it, even if the information itself is timely and accurate. In spite of today's technological flexibility in delivering complex data forms, formats, and relationships, future IT departments should ensure they lean more toward providing information services in ways that achieve organizational goals and focus less on the technology delivering the information. This is especially pertinent as users do not always realize how much help they need using technology intended to improve their organizations' performance.

This view summarizes our interviews with CIOs and a roundtable discussion we conducted in May 2007 with a dozen senior CIOs representing organizations with aggregate annual sales of more than $300 billion, including Cooper Standard, Federal Mogul, General Motors, Oakland County, Oakland University, and Penske Corporation from a cross section of industries, including manufacturing, services, and government. The CIOs said IT's greatest value is in managing the information their organizations depend on to do business, regardless of the technology they use [1]. Indeed, the corporate title of Mario Leone of Federal Mogul, an automotive supplier with annual sales of $6.5 billion, recently changed from chief information officer to chief information services officer to stress the information-services aspect of IT. Our view is further supported by a corporate case study we conducted in 2004–2005.[1]

Separating information services from data-centered delivery technology requires that senior IT management change its thinking. By taking an information-services approach, IT personnel need not concern users with technology considerations or involve them in decisions about how information is gathered, processed, or presented. The technology is of interest only to IT personnel. Otherwise, business executives may be overwhelmed by technology, thus turning them off to IT [4]. It also makes them reluctant to use the information, casting IT's potential benefit as only "hidden potential" [2].

How did the perception that IT delivers technology rather than business value come to be so pervasive? Deploying IT was information-driven 40 years ago when the field was called "management information systems" and, later, "information systems." Users had minimal involvement in processing data

LISA HANEY

[1]Ragowsky's and Gefen's study "Why Information Systems Management Is in Trouble and How to Save It" was accepted for publication in *Communications.*

and generating information. Despite the physical aspects of the technology—mainframes, punched cards, hard-copy printed reports—the emphasis was on information and its business applications primarily for report preparation, transaction processing, and business processes (such as bookkeeping). Users trusted IT experts to deal with what they viewed as complicated technology. Although managers did not understand the technology, they were aware of its business benefits and paid for it as a cost center.

In the late 1970s and early 1980s, online processing was still mainframe-based and closely guarded by IT professionals. Minicomputers were increasingly reliable and affordable as business computers, with bigger companies using them in distributed IT strategies. When PCs appeared, their relatively low price enabled greater access for whole companies and individual users alike. Consequently, end users were more familiar with IT and began acquiring and developing their own applications. Hardware, software, and telecommunications vendors took note. By the 1990s, they had changed the name of the field from IS to IT as they pushed the latest technology solutions. This shift transformed the IT function from information provider to technology promoter. The vendors then began bypassing the organizations' IT leaders, approaching users directly.

This marketing approach also included the hidden cost of complexity, leading to user resistance and weakening the traditional IT-user relationship. Many users were indeed intimidated by "too much" technology [4]. Technological complexity also reduced user satisfaction with the related information, along with respect for IT personnel. Despite vendor promises that their hardware and software could do whatever users said they wanted, users often found the technology actually made it more difficult to generate information. Many users blamed IT personnel—ironic because IT personnel were often not involved in and frequently recommended against such deals. As a result, many business managers even today do not realize the business benefits of their organizations' own technology. Consequently, they may minimize the IT budget, treating IT as purely technical support, ignoring the information component (the I in IT) [2]. Ironically, the CIO of a large manufacturer with $6 billion in annual sales told us that in executive meetings he is regularly asked to fix dysfunctional video projectors because he is viewed as the number-one technology expert in the room; the CIO of a major city in Michigan said the same.

This lack of understanding and appreciation may be partly the fault of IT personnel using technological terminology when interacting with users, at least in part because they don't know a better way. This is not just an IT phenomenon. For example, most purchasers of costly technology-related consumer products like cars, TVs, and PCs do not want to know how they are produced or the scientific principles on which they depend. They also react unfavorably to technical manuals, often refusing to read them [4]. One lesson is that IT personnel must learn to interact with users to identify information needs without mentioning the latest technical enhancement. Only later, and independent of users, should IT personnel deploy their technological skills to identify the technology needed to support an organization's information needs.

This approach reorients the traditional systems/business analyst function in the direction of information services, embracing users and managers as partners. IT departments could then identify opportunities to add value by delivering additional information, rather than trying to limit themselves to developing new ways to deliver more data.

Consider how a business organization approaches its potential customers. It typically employs marketing specialists to conduct market research, aiming to identify what drives and excites their needs, as well as how much they are willing to pay for products and services (perception of value). These specialists do not invite potential customers into the organization's technological deliberations. Only after the market is understood in multiple dimensions are R&D specialists assigned to work on products. Likewise, only after first "studying" their customers should IT "marketing" personnel (business analysts) transfer their findings to IT R&D specialists (designers and programmers) who evaluate the internal cost of addressing these needs by developing systems. IT management must know the value of the added information (provided by the IT marketing personnel who learn it from users) and the cost of the development (provided by IT R&D). It is then able to use the predicted added value the additional information provides (cost/benefit analysis) to support informed go/no-go decisions. Promoting the information component of IT could refocus IT on its information-services origins. Analysts would be expected to identify information needs and how they help users and their organizations generate business value. Having analysts focus on these needs also means less user involvement with technology per se.

IT departments often move directly to technological solutions without first understanding users' business responsibilities. Such haste inevitably exposes users to "solutions" to "problems" they don't necessarily have. Thus, IT may underserve its constituents by focusing instead on the technological fulfillment of processes and tasks, inevitably weakening the IT-user relationship. Meanwhile, users are unable to take responsibility for their own information needs when IT personnel confuse business information with technology [3]. As reflected in the popular business media [2], top executives in many companies fail to recognize IT's hidden value because they see only technology.

We documented such a dysfunctional relationship in our 2004–2005 case study. The company's CIO identified a gap between IT and users who did not utilize all the potential features of the company's technology and worse did not trust the IT unit. Consequently, the company suffered from an inability to address its information needs. For example, in one plant users did not know they could download information directly from a central database for use in Excel spreadsheets. Instead, they printed hard-copy reports from the ERP system, then manually entered the information into the spreadsheets. Other users were not aware of the system's ability to manage information for quality-assurance purposes and handled the information manually. One underlying factor was that IT personnel thought more about technological solutions than about the organization's information needs and their business implications. Trust was ultimately established between users and IT once a particular project leader taught IT to concentrate on users' business needs and avoid purely technological terminology. Consequently, the users learned more about IT and the business information benefits it was designed to provide.

IT personnel must learn to interact with users to identify information needs without mentioning the latest technical enhancement.

IT professionals should be aware of their responsibility for supporting their organizations' information needs through technology. It is the information, not the technology, they value, using it to increase their own personal value to the organization. **C**

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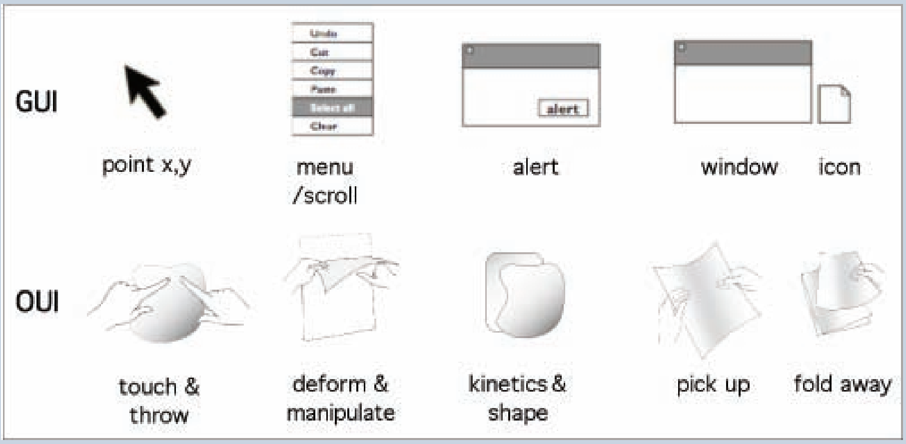
ORGANIC USER INTERFACES

BY ROEL VERTEGAAL AND IVAN POUPYREV, GUEST EDITORS

Throughout the history of computing, developments in human-computer interaction (HCI) have often been preceded by breakthroughs in display and input technologies. The first use of a cathode ray tube (CRT) to display computer-generated (radar) data, in the Canadian DATAR [6] and MIT's Whirlwind projects of the early 1950s, led to the development of the trackball and light pen. That development, in turn, influenced Sutherland's and Engelbart's work on interactive computer graphics, the mouse, and the graphical user interface (GUI) during the early 1960s. According to Alan Kay [3], seeing the first liquid crystal display (LCD) had a similar disruptive effect on his thinking about interactivity at Xerox PARC during the early 1970s. His vision of Dynabook led to the development of Smalltalk, the Alto GUI (1973), and eventually, the Tablet PC [2]:

"... Another thing that we saw in 1968 was a tiny 1″ square first flat panel display down at the University of Illinois. We realized it was going to be a matter of years until you could put all the electronics... on the back of a flat panel display, which I later came to call the Dynabook."



Developments in human-computer interaction are often preceded by breakthroughs in display technologies.

Display Technology	CRT	LCD	HUD/ 3D	Projection/ Haptic	E-Ink Flexible and Kinetic
User Interface	GUI	Ubicomp and Context-Aware	VR/AR and Wearables	TUI	OUI

This diagram shows how OUI interaction styles might eventually relate to those found in traditional GUIs. In OUIs, simple pointing will be supplanted by multi-touch manipulations. Although menus will still serve a purpose, many functions may be triggered through manipulations of shape. OUIs will take the initiative in user dialogue through active shape-changing behaviors. Finally, OUIs' superior multi-tasking abilities will be based on the use of multiple displays with different shapes for different purposes. These will appear in the foreground when picked up or rolled out, and they will be put away when no longer needed.

Over the past few years, another quiet revolution has been brewing in some of the fundamental technologies used to create digital computing devices. While still limited in resolution, speed, color, and size, pixels made of electrophoretic ink (E-Ink) and light-emitting polymer technologies, combined with advances in organic thin-film circuit substrates, now allow for displays so thin and flexible they are beginning to resemble paper (see Figure 1). Display manufacturers are beginning to weave textile displays as well, by threading large arrays of tiny LEDs into fabrics and furniture. In parallel to these developments, advances in sensor technologies now allow for input devices to track the position of multiple fingers, twists, pressure, and acceleration on any surface. On the output side, miniature actuating devices, shape memory polymers, multi-layer piezoelectric sandwiches, and tiny ultrasound motors are beginning to allow for "claytronic" interaction devices, with displays that actively reshape themselves [1]. All this is happening against a backdrop of microprocessors that are faster, smaller, and more energy-efficient than ever before, powered by super-thin, flexible polymer batteries that withstand tens of thousands of bends. Such phenomenal technological breakthroughs are opening up entirely new design possibilities for HCI, to an extent perhaps not seen since the days of the first GUIs.

In this special section, we attempt to map out a future where these technologies are commonplace. A future led by disruptive change in the way we will use digital appliances: where the shape of the computing device itself becomes one of the key variables of interactivity. We have invited a number of top researchers in this field to share their ideas on this topic. This section covers three tightly knit themes, which define what we refer to as an Organic User Interface (OUI):

1. Input Equals Output: Where the display is the input device.
The developments of flexible display technologies will result in computer displays that are curved, flexible, or any other form, printed on couches, clothing, credit cards, or paper. How will we interact with displays that come in any shape imaginable? What new interaction principles and visual designs become possible when curved computers are a reality? One thing is clear: current point-and-click interfaces designed for fixed planar coordinate systems, and controlled via some separate special-purpose input device like a mouse or a joystick, will not be adequate. Rather, input in this brave new world of computing will depend on multi-touch gestures and 3D-surface deformations that are performed directly on and with the display surface itself. In future interfaces, input and output design spaces are thus merged: *the input device is the output device.* We have invited two authors to discuss their work on this

topic. Jun Rekimoto will share his thoughts on new directions in skin-based inputs—interaction techniques that are not only multi-touch, but that potentially follow any shape or form. A sidebar by Carsten Schwesig argues the finer points of the use of analog rather than discrete inputs for optimal organic interaction design.

Figure 1. Raedius rollable cell phone prototype by Polymer Vision [4].

2. Function Equals Form: Where the display can take on any shape.
Today's planar, rectangular displays, such as LCD panels, will eventually become secondary when any object, from a credit card to a building, no matter how large, complex, dynamic or flexible will be wrapped with high resolution, full-color, interactive graphics. Several pioneering projects are already exploring this future, such as the D20 concept that proposed an interface for an icosohedral display [5] (see Figure 2). One important observation that emerges from such experimentation is that the *form of the display equals its function*. In other words, designers should tightly coordinate the physical shape of the display with the functionality that its graphics afford. Three contributions in this section address this topic of research. David Holman and Roel Vertegaal further elaborate on design principles of OUIs, as grounded in their experimentation with flexible computers and curved-computer interactions. In accompanying sidebars, Elise Co and Nikita Pashenkov present an overview of the new flexible display technologies that underlie OUIs, while Eli Blevis ponders the implications on sustainability of the potential widespread use of these technologies in product design.

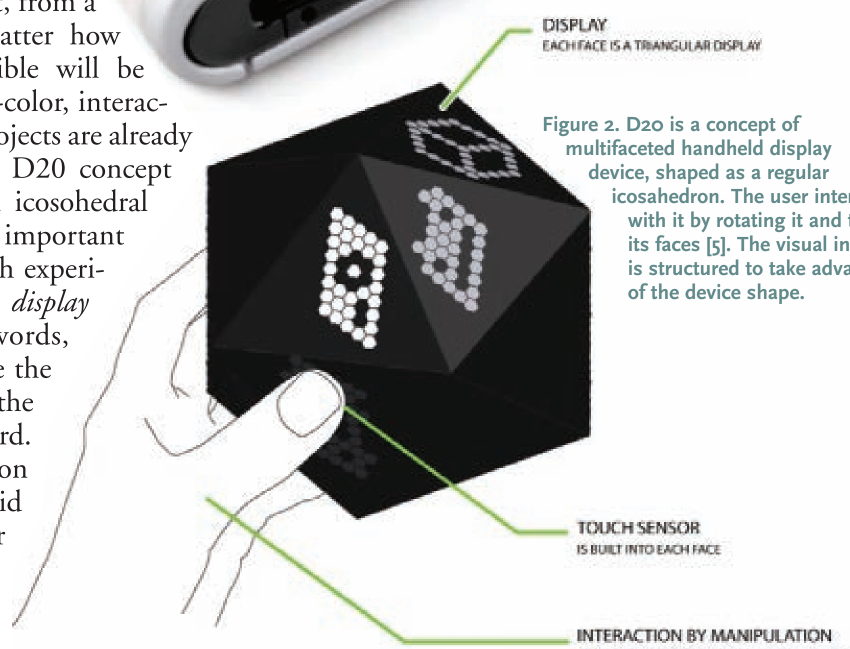


Figure 2. D20 is a concept of multifaceted handheld display device, shaped as a regular icosahedron. The user interacts with it by rotating it and touching its faces [5]. The visual interface is structured to take advantage of the device shape.

3. Form Follows Flow: Where displays can change their shape.
In the foreseeable future, the physical shape of computing devices will no longer necessarily be static. On the one hand, we will be able to bend, twist, pull, and tear apart digital devices just like a piece of paper or plastic. We will be able to fold displays like origami, allowing the construction of complex 3D structures with continuous display surfaces. On the other hand, augmented with new actuating devices and materials, future computing devices will be able to actively alter their shape. *Form will be able to follow the flow of user interactions* when the display, or entire device, is able to dynamically reconfigure, move, or transform itself to reflect data in physical shapes. The 3D physical shape itself will be a form of display, and its kinetic motion will become an important variable in future interactions. In this sec-

How will we interact with displays that come in any shape imaginable? What new interaction principles and visual designs become possible when curved computers are a reality?

tion Amanda Parkes, Ivan Poupyrev, and Hiroshi Ishii examine kinetic interaction design as an area of research in OUI. In a sidebar, artist Sachiko Kodama gives her thoughts on the use of physical transformability in interactive art forms. Finally, architects Kas Oosterhuis and Nimish Biloria outline their vision of a future in which entire buildings and cities are made out of networks of actuated, interactive, organic computers.

ORGANIC USER INTERFACES

These three general directions together comprise what we refer to in this section as Organic User Interfaces: User interfaces with non-planar displays that may actively or passively change shape via analog physical inputs. We chose the term *"organic"* not only because of the technologies that underpin some of the most important developments in this area, that is, organic electronics, but also because of the inspiration provided by millions of organic shapes that we can observe in nature, forms of amazing variety, forms that are often transformable and flexible, naturally adaptable and evolvable, while extremely resilient and reliable at the same time. We see the future of computing flourishing with thousands of shapes of computing devices that will be as scalable, flexible, and transformable as organic life itself.

We should note that the OUI vision is strongly influenced by highly related areas of user interface research, most notably Ubiquitous and Context-aware Computing, Augmented Reality, Tangible User Interfaces, and Multi-touch Input. Hiroshi Ishii opens this section by exploring some of those historical trends that led to OUIs. Naturally, OUIs incorporate some of the most important concepts that have emerged in the previous decade of HCI, in particular embodied interaction, haptic, robotic, and physical interfaces, computer vision, the merging of digital and physical environments, and others. At the same time, OUIs extend and develop those concepts by placing them in a framework where our environment is not only embedded with billions of tiny networked computers, but where that environment *is* the interface, physically and virtually reactive, malleable, and adaptable to the needs of the user.

There has always been a mutually beneficial symbiotic relationship between advances in basic computing technologies and HCI research. New technologies inspire new interface paradigms, while new interfaces utilizing these emerging technologies encourage their continued refinement by revealing aspects most useful in their application. We hope the ideas and projects presented in this special section encourage a dialogue on organic design that inspires designers and HCI researchers to invent that future reality in which these exciting technologies will benefit people in their natural ecologies. And we hope these stories inspire physicists and engineers alike to continue inventing and refining the very basic technologies so critical to realizing the future of computing. C

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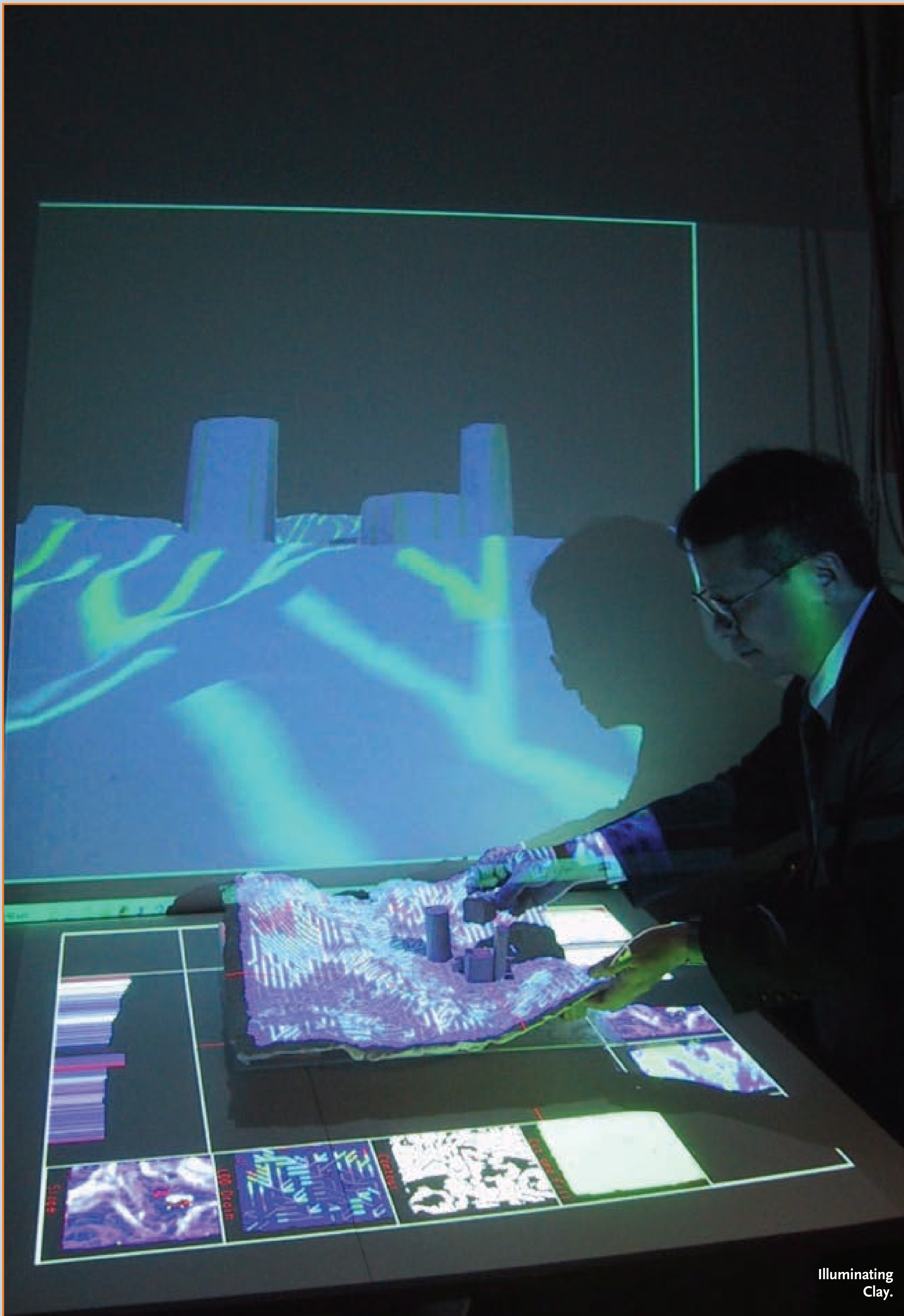
THE TANGIBLE USER INTERFACE AND ITS EVOLUTION

Users sculpt and manipulate digital information through such tangible media as clay, sand, and building models, coupled with underlying computation for design and analysis.

BY HIROSHI ISHII

Through eons of human evolution, we have developed sophisticated skills for sensing and manipulating our physical environment. However, most of them are not used when interacting with the digital world where interaction is largely confined to graphical user interfaces. With the commercial success of the Apple Macintosh and Microsoft Windows systems, the GUI has become the standard paradigm for human-computer interaction.

GUIs represent information (bits) in the form of pixels on bit-mapped displays. These graphical representations are manipulated with generic remote controllers (such as mice and keyboards). By decoupling representation (pixels) from control (input devices) this way, GUIs are malleable enough to graphically emulate a variety of media. However, when interacting with the GUI world, we cannot take advantage of our evolved dexterity or utilize our skills in manipulating physical objects (such as building blocks or clay models) (see Figure 1).



Illuminating Clay.

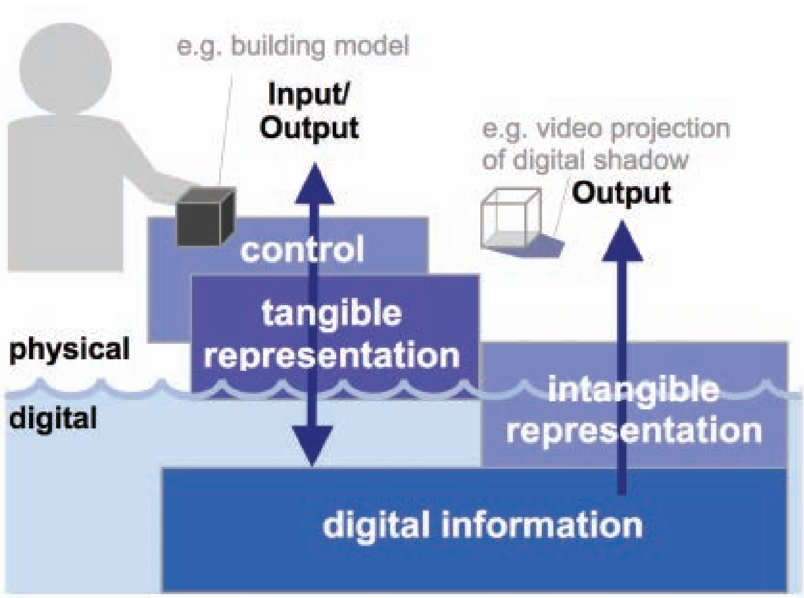


Figure 1. By giving tangible (physical) representation to digital information, tangible user interfaces make information directly graspable and manipulable through haptic feedback. Intangible representation (such as video projection) may complement tangible representation, synchronizing with it.

The Tangible Media Group at the MIT Media Laboratory moved from GUIs to tangible user interfaces (TUIs) in the mid-1990s. TUIs represented a new way to embody Mark Weiser's (former chief scientist at Xerox PARC) vision of ubiquitous computing by weaving digital technology into the fabric of the physical environment, rendering the technology invisible [9]. Rather than make pixels melt into an interface, TUIs use physical forms that fit seamlessly into a user's physical environment. TUIs aim to take advantage of these haptic-interaction skills, an approach significantly different from GUIs. The key TUI idea remains: give physical form to digital information [3], letting serve as the representation and controls for its digital counterparts. TUIs make digital information directly manipulatable with our hands and perceptible through our peripheral senses through its physical embodiment (see Figure 1).

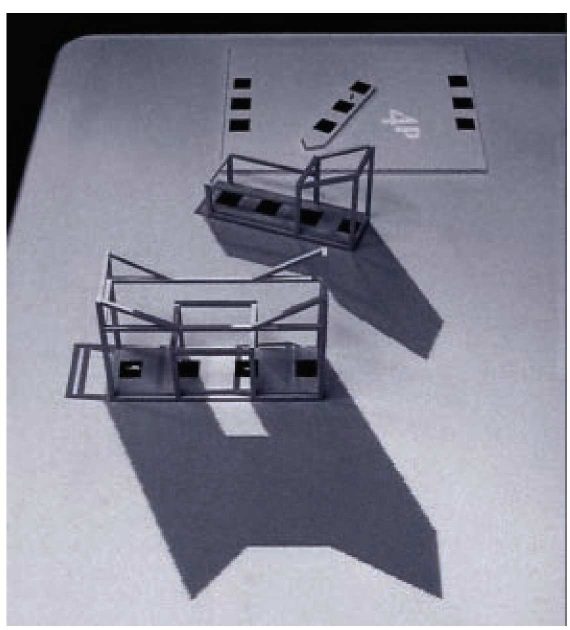


Figure 2. Urp and shadow simulation. Physical building models that cast digital shadows and a clock tool to control time of day (position of the sun).

URP: FIRST-GENERATION TUI

To illustrate basic TUI concepts, I start with the Urban Planning Workbench, or Urp (developed by the Tangible Media Group in 1999), as an example early TUI [8]. Urp uses scaled physical models of architectural buildings to configure and control an underlying urban simulation of shadow, light reflection, wind flow, and traffic congestion (see Figure 2). In addition to a set of building models, Urp provides interactive tools for querying and controlling the parameters of the urban simulation, most notably position and rotation control via the physical models. Also included are a clock tool to change the position of the sun, a material wand to change the building surface between bricks and glass (with light reflection), a wind tool to change wind direction, and an anemometer to measure wind speed.

The physical building models in Urp cast digital shadows onto the workbench surface (via video projection) corresponding to solar shadows at a particular time of day. This time, representing the position of the sun, can be controlled by turning the physical hands of a "clock tool," like the one in Figure 2. The building models can be moved and rotated, with the angle of their corresponding shadows transformed depending on position and time of day.

Moving the hands of the clock tool can cause Urp to simulate a day of shadow movement among the buildings. Urban planners can identify and isolate intershadowing problems (shadows cast on adjacent buildings) and reposition buildings to avoid areas that are needlessly dark; alternatively, they can maximize light among the buildings.

In Urp, the physical models of buildings are tangi-

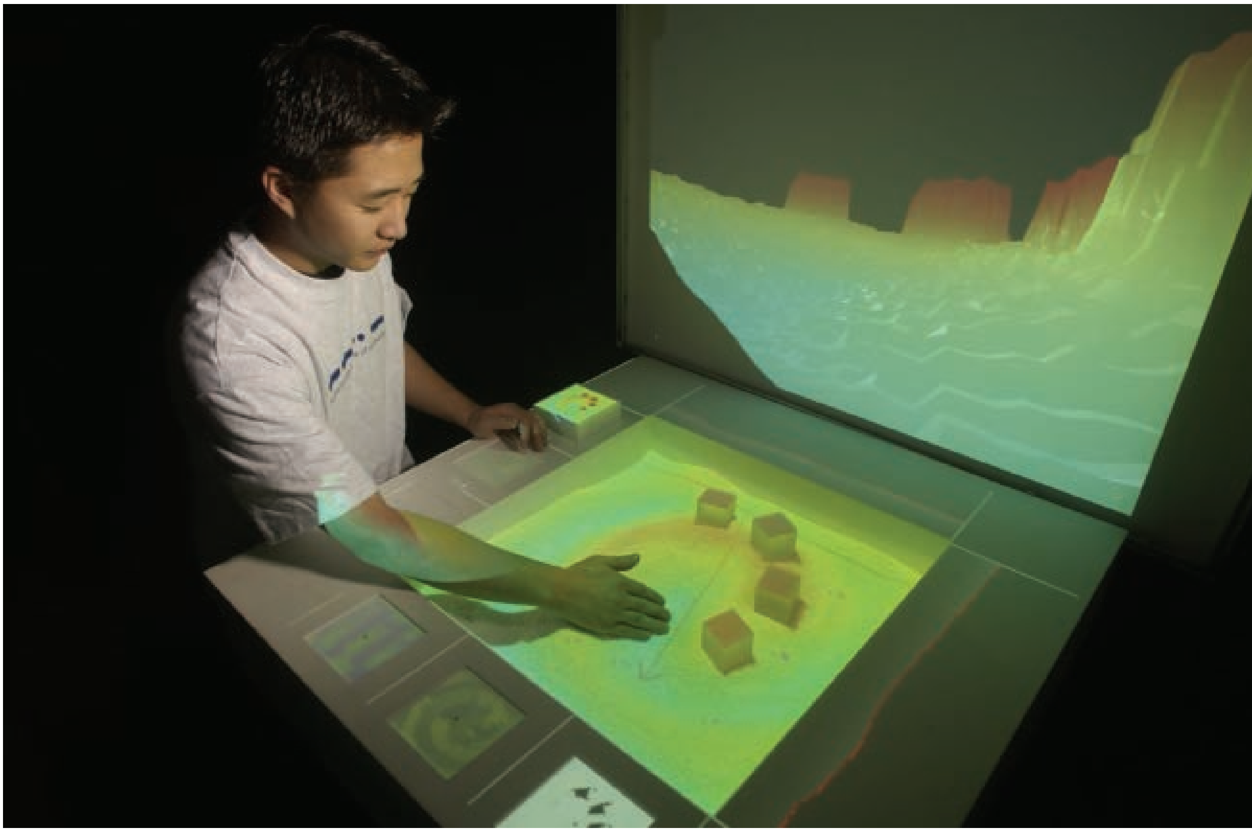


Figure 3. SandScape. Users alter the form of the landscape model by manipulating sand while seeing the resultant effects of computational analysis generated and projected onto the surface of sand in real time.

ble representations of digital models of the buildings. To change their location and orientation, users simply grab and move the physical model, rather than a mouse, to point to and drag a graphical representation on a screen. The physical form of Urp's building models and the information associated with their position and orientation on the workbench represent and control the state of the urban simulation.

Although standard GUI interface devices (such as keyboards, mice, and screens) are also physical, the physical representation in a TUI provides an important distinction. The physical embodiment of the buildings (representing the computation in building dimensions and location) allows for the tight coupling of control of the object and manipulation of its parameters in the underlying digital simulation.

In Urp, the building models and interactive tools are physical representations of digital information (shadow dimensions and wind speed) and computational functions (shadow interplay). The physical artifacts also serve as controls for the underlying computational simulation (specifying the locations of objects). The specific physical embodiment allows dual use in representing the digital model and the control of the digital representation.

However, Urp lacks the ability to change the forms of tangible representations during user interaction. Users must use a predefined finite set of fixed-form objects (building models in this case) and change only the spatial relationship among them, not the form of individual objects. All tangible objects in Urp must be predefined (physically and digitally) and are unable to change their forms on the fly. This is why the Tangible Media Group designed the second generation of "organic" TUI.

SANDSCAPE: SECOND-GENERATION TUI

The advent of new sensing and display technologies made it possible to add dynamic form development into TUIs, suggesting movement toward new digital/physical materials that seamlessly couple sensing and display capabilities. Rather than using predefined discrete objects with fixed forms, the Tangible Media Group developed new types of organic TUIs that utilize continuous tangible material (such as clay and sand) for rapid form sculpting for landscape design; examples include Illuminating Clay [6] and SandScape [2]. With the advent of flexible materials that integrate fully flexible sensors and displays, this category of organic TUI shows great potential to express ideas in tangible form.

SandScape [2] is an organic tangible interface for designing and understanding landscapes through a variety of computational simulations based on physical sand (see Figure 3). Users view these simulations as they are projected onto the surface of a sand model representing the terrain. They choose from a variety of simulations highlighting the height, slope, contours, shadows, drainage, or aspect of the landscape model.

Users alter the form of the landscape model by manipulating sand with their hands, seeing the resultant effects of computational analysis generated and projected onto the surface of the sand in real time. The project demonstrates how TUIs take advantage of our natural ability to understand and manipulate physical forms while harnessing the power of computational simulation to help us understand model representations. SandScape, which uses optical techniques to capture the geometry of a landscape model, is less accurate than its predecessor, Illuminating Clay, which used laser range finders to capture the geometry of a physical clay model [6].

SandScape and Illuminating Clay both demonstrate the potential advantage of combining physical and digital representations for landscape modeling and analysis. The physical clay and sand models convey spatial relationships that are intuitively and directly manipulated by hand. Users also insert any found physical objects directly under the camera. This approach allows them to quickly create and understand highly complex topographies that would be difficult and time-consuming to produce through conventional computer-aided design tools. This "continuous and organic TUI" approach makes better use of our natural ability to discover solutions through direct manipulation of physical objects and materials.

CONCLUSION

TUIs give physical form to digital information and computation, facilitating the direct manipulation of bits. The goal is to empower collaboration, learning, and decision making through digital technology while taking advantage of our human ability to grasp and manipulate physical objects and materials. Here, I've introduced the genesis and evolution of TUIs over the past 10 years, from rigid discrete interface toward organic and malleable materials that enable dynamic sculpting and computational analysis using digitally augmented continuous physical materials. This new type of TUI delivers rapid form giving in combination with real-time computational feedback.

In addition to rapid form giving, actuation technology plays a critical role in making the interface more organic and dynamic. The Tangible Media Group is exploring the new genre of TUIs that incorporates actuation mechanisms to realize kinetic memory for educational toys like Curlybot [1] and Topobo [7]. It is also designing a new generation of tabletop TUIs that utilize actuation to make tangible objects behave more actively, dynamically representing the internal computational state; examples include the Actuated Workbench [4] and physical intervention in computational optimization, or PICO [5].

I hope the TUI evolution I've explored here will contribute to the future discussion of malleable, dynamic, organic interfaces that seamlessly integrate sensing and display into soft and hard digital/physical material. **C**

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ORGANIC INTERACTION TECHNOLOGIES: FROM STONE TO SKIN

Interaction with computers can make use of our whole physical and even emotional selves, as demonstrated by such emerging systems as HoloWall, SmartSkin, and PreSense.

BY JUN REKIMOTO

The mouse is the most successful and popular input device in the history of computing. However, it will never be the ultimate input device because it does not completely bring out its users' sophisticated manipulation skills. A mouse gives us control of only a single position (x,y) at any given moment in time, along with additional button presses (on/off). Feedback related to the input is normally available only as visual information. On the other hand, in physical manipulation, we easily control multiple points and continuous parameters (such as pressure) at the same time. Feedback is not limited to sight but often includes touch, sound, temperature, and even air movement. Feedback itself is also more tightly unified with input than in traditional graphical user interfaces (GUIs), where input and output are often separate. The part(s) of our body we use for interaction is not limited to fingers; the palm, arm, even the entire body are all potentially usable. Several recent approaches have sought to incorporate these human manipulation skills into human-computer interaction. I use the terms "organic" and "organic interaction" for such interfaces, because they more closely resemble natural human-physical and human-human interaction (such as shaking hands and gesturing).

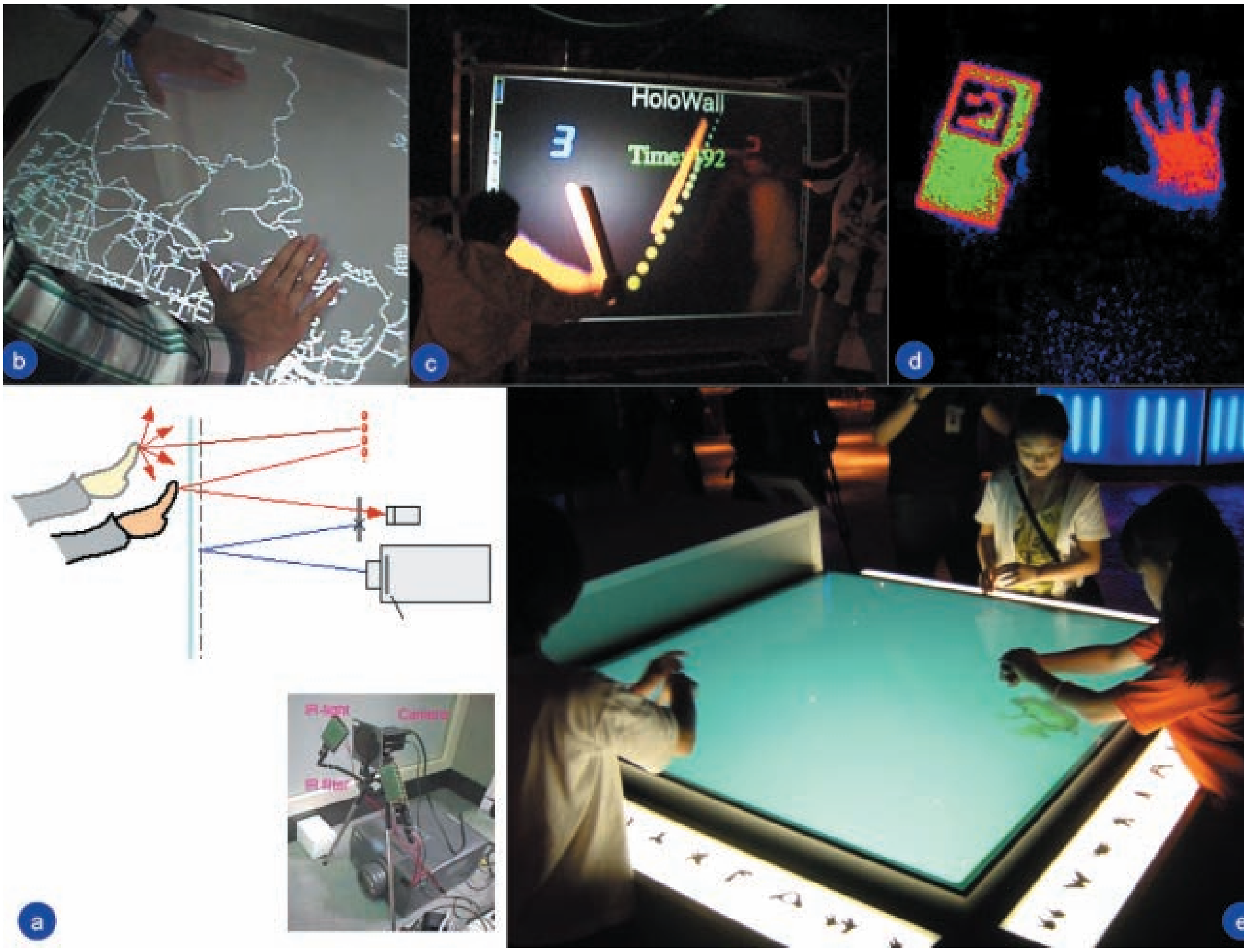

Figure 1. HoloWall interactive surface system [5]. The camera (with IR filter) captures the image on the back surface of a rear-projection sheet illuminated by IR lights behind the sheet. (a) Sensor configuration; (b) example multi-touch interaction; (c) physical instruments for interaction; (d) captured image for recognition; and (e) interactive table with hand shapes as input.

The table here outlines the features of organic interaction, comparing them with the features of traditional user interfaces. Even as the number of novel interaction methods involving sensing technologies has grown, such methods have been used mainly for some special purpose (such as interactive art). Myron Krueger's "Videoplace" (bubblegum.parsons.edu) was an early example (early 1970s); in it, a video camera was used to capture a user's body silhouette, and the full-body shape, not just finger positions, are used as input to the computer system. In the next few years, as the cost of sensing and computation comes down, such organic interaction technologies are likely to be viable alternatives to traditional mouse-based interaction. Here, I explore notable examples and discuss future research topics needed to advance organic user interfaces and make them more mainstream.

	Traditional UI	Organic UI
Metaphor	tools/stone	skin/membrane
Number of interaction points	single	plural or infinite
State	discrete (button On/Off)	analog (continuous)
Input	position (x, y)	shape
Output (feedback)	visual	tactile and others
I/O coupling	separated	unified
Distance to target	contact	proximity
Purpose	perform commands	communication
Place of interaction	computer screen	anywhere

Traditional GUI and organic interaction compared.

HOLOWALL

HoloWall [5] is a camera-based interactive wall/table system that uses a combination of infrared (IR) camera and array of IR lights installed behind the wall (see Figure 1). The camera captures the images on the back surface of the wall (illuminated by the IR lights). An IR-blocking filter built into the LCD projector ensures that the camera is not affected by the projected image.

Since the rear-projection panel is semi-opaque and diffusive, the user's hand shape in front of the screen is not visible to the camera when the hand is far (more than 30cm) from the screen. When the user moves a finger close enough to the screen (10cm or less), the

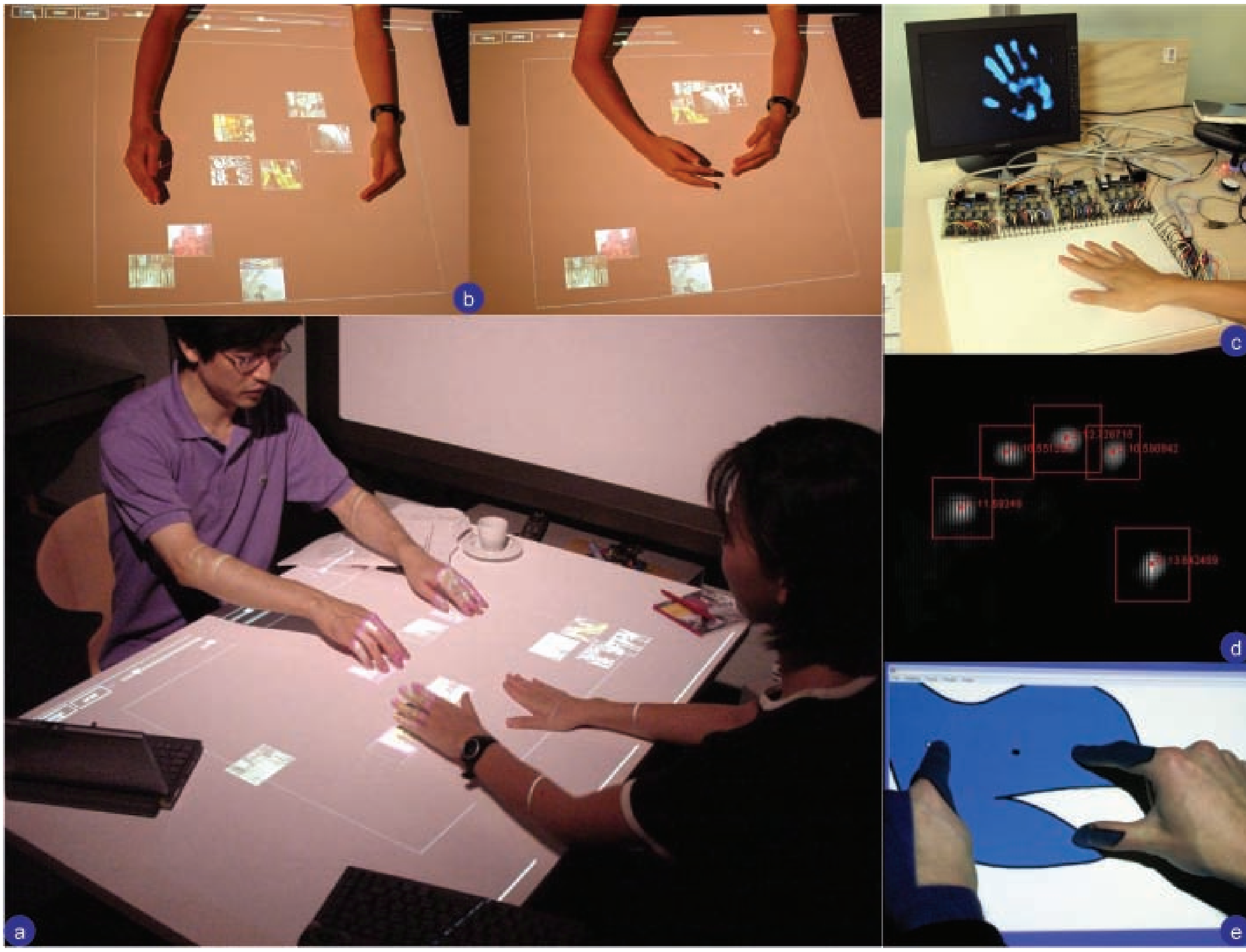

Figure 2. SmartSkin, an interactive surface system based on capacitive sensing [7]. (a) Collaborative table system allowing multi-hand, multi-person interaction; (b) object movement using arm motion; (c) and (d) results of sensing showing hand shape and multiple finger points; and (e) the algorithm As-Rigid-As-Possible Shape Manipulation [4] in SmartSkin multi-touch interaction.

finger reflects IR light and thus becomes visible to the camera. With a simple image-processing technique (such as frame subtraction), the finger shape is separated from the background.

Using this sensing principle, HoloWall distinguishes multiple hand and finger contact points, enabling typical multi-touch interactions (such as zooming with two hands, as in Figure 1c). Moreover, it also recognizes the human hand, arm, body, physical objects (such as rods), and visual patterns (such as 2D barcodes attached to the object), as in Figure 1c and Figure 1d).

Figure 1c shows two users playing a ping-pong game using HoloWall demonstrated at the SIGGRAPH conference in 1998. Although the system was originally designed for hand and body gestures, some participants used other physical objects as instruments for interaction; the system recognizes any light-reflecting object. Such dynamic expandability is an interesting feature of organic user interfaces.

Note that a sensing principle similar to that of HoloWall is also used in other interactive-surface systems (such as the Microsoft Surface, www.microsoft.com/surface/). Perceptive Pixels [2] is another optical multi-touch input system, though it is based on a sensing principle different from the one used by HoloWall.

SMARTSKIN

SmartSkin (see Figure 2) is a multi-touch interactive surface system based on capacitive sensing [7] that uses a grid-shaped antenna to measure hand and finger proximity. The antenna consists of a transmitter and receiver electrodes (copper wires). The vertical wires are transmitter electrodes; the horizontal wires are receiver electrodes. When one transmitter is excited by a wave signal (typically several hundred kHz), the receiver receives the signal because each crossing point (transmitter/receiver pair) functions as a capacitor. The magnitude of the received signal is proportional to the frequency and voltage of the transmitted signal, as well as to the capacitance between the two electrodes. When a conductive, grounded object approaches a crossing point, it

The current level of development of organic user interfaces is the equivalent of where the mouse was when it was first invented.

capacitively couples to the electrodes and drains the wave signal. As a result, the received signal amplitude becomes weak. Measuring this effect makes it possible to detect the proximity of a conductive object (such as a human hand).

Since the hand detection is done through capacitive sensing, all the necessary sensing elements can be completely embedded in the surface. Unlike camera-based systems, the SmartSkin sensor is not affected by changes in the intensity of the environmental lighting. The surface is also not limited to being flat; the surface of any object, including furniture and robots, potentially provides such interactivity, functioning like the skin of a living creature.

The system recognizes the effect of the capacitance change when the user's hand is placed 5cm–10cm from the table. To accurately determine the hand's position (the peak of the potential field), SmartSkin uses bi-cubic interpolation to analyze the sensed data. The position of the hand can be determined by finding the peak on the interpolated curve. The precision of the calculated position is much finer than the size of a grid cell (10cm). The current implementation has an accuracy of 1cm.

SmartSkin's sensor configuration also enables shape-based manipulation that does not explicitly use the hand's 2D position. A potential field created by sensor inputs is instead used to move objects. As the hand approaches the surface of the table, each intersection of the sensor grid measures the capacitance between itself and the hand. This field helps define various rules of object manipulation. For example, an object that descends to a lower potential area is repelled from the hand. The direction and speed of the object's motion can be controlled by changing the hand's position around the object.

In my lab's tests, many SmartSkin users were able to quickly learn to use the interface even though they did not fully understand its underlying dynamics. Many users used two hands or even their arms. For example, one can sweep the table surface with an arm to move a group of objects, and two arms can be used to trap and move objects, and (see Figure 2b).

Using the same sensing principle with a more dense grid antenna layout, SmartSkin determines the shape of a human hand (see Figure 2c and Figure 2d). The peak detection algorithm can also be used; in it, the algorithm, rather than tracking just one position of the hand, is able to track multiple positions of the fingertips.

An algorithm known as As-Rigid-As-Possible Shape Manipulation deforms objects with multiple control points [4]; Figure 2e shows its implementation in SmartSkin. Users manipulate graphical objects directly with multiple finger control points.

DIAMONDTOUCH

DiamondTouch [1] developed at Mitsubishi Electric Research Laboratories is another interactive table system based on capacitive sensing. Its unique feature is the ability to distinguish among multiple users. The grid-shaped antenna embedded in the DiamondTouch table transmits a time-modulated signal. Users sit in a special chair with a built-in signal-receiving electrode. When a user's finger touches the surface, a capacitive connection from the grid antenna to the signal-receiving chair is established through the user's body. The connection information is then used to determine the user's finger position on the surface, as well as the uniquely identified user manipulating the surface. Since the DiamondTouch table transmits a modulated signal, multiple users are able to operate the same surface simultaneously without the system losing track of the identity of any user. DiamondTouch also supports semi-multi-touch operation in which "semi" means (despite some ambiguity) the ability to detect multiple points. For instance, when a user touches two points—(100, 200) and (300, 400)—the system is unable to distinguish them from another two points—(100, 400) and (300, 200). However, performing simple multi-touch interactions (such as pinching, or controlling scale with the distance between two fingers), this ambiguity is not a problem.

PRESENSE: TOUCH- AND PRESSURE-SENSING INTERACTION

Touch-sensing input [3] extends the mouse's usability by adding a touch sensor. While the buttons of a normal mouse have only two states (nonpress and press), the button in touch-sensing input provides three states (nontouch, touch, and press). The additional state allows more precise control of the system. For example, the toolbox of a GUI application automatically picks up more tools when a user moves a cursor to a toolbar region with a finger touch of the button.

Pressure is another useful input parameter for organic interaction. We intuitively use and control pressure for natural communication (such as when shaking hands). With a simple pressure sensor (such as a force-sensitive resister) embedded in a regular mouse or touchpad, the device easily senses finger pressure by measuring the pressure sensor's resister values.

PreSense [8] is a touch- and pressure-sensing input device that uses finger pressure, as well as finger position (see Figure 3). It consists of a capacitive touchpad, force-sensitive resister pressure sensor, and actuator for tactile feedback. It also recognizes finger contact by measuring the capacitive change on the touchpad surface. Combining pressure sensing and tactile feedback, it also emulates a variety of buttons (such as one-level and two-level) by setting thresholds to pressure parameters. For example, a user can "soft press" the target to select it and "hard press" it to display a pop-up menu.

Analog pressure sensing enables users to control continuous parameters (such as the scale of the displayed image). The finger contact area is used to distinguish between scaling directions (scale-up and scale-down). By changing the position of the finger slightly, one can control both zooming-in and zooming-out with one finger (see Figure 3b).

Pressure is useful for explicit parameter control (such as scaling) while offering the possibility of sensing the user's implicit or emotional state. When a user is, say, frustrated with the system, his or her mouse button pressure might change from the normal state, and the system would be able to react to that frustration.

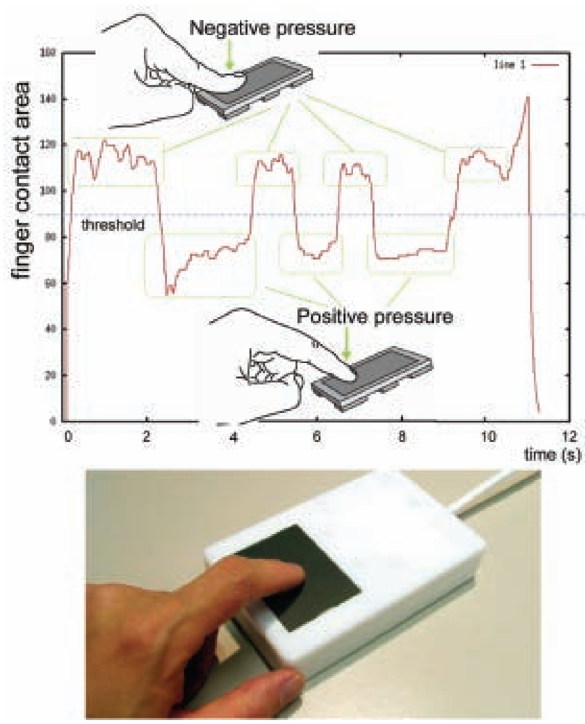

Figure 3. PreSense 2D input device enhanced with pressure sensors. Users add pressure to control analog parameters (such as scaling) and specify "positive" and "negative" pressures by changing the size of the finger contact area on the touchpad surface. PreSense can be combined with tactile feedback to emulate a discrete button press with "click" sensation.

Finger input with pressure, combined with tactile feedback, is the most common form of natural interaction. Like Shiatsu (Japanese finger-pressure therapy), users of PreSense feel and control the performance of computer systems directly.

RESEARCH ISSUES

Because organic user interfaces represent such a new and emerging research field, many related research challenges and issues require further study. In what follows, I outline four of them:

Interaction techniques for OUIs. GUIs have a long history and incorporate a large number of interaction techniques. When the mouse was invented by Douglas Englebart at Stanford Research Institute in 1963, it was used only to point at on-screen objects. Development of mouse-based interaction techniques (such as pop-up menus and scrollbars) followed. The current level of development of organic user interfaces is the equivalent of where the mouse was when first invented. For multi-touch interaction, only a simple set of techniques (such as zooming) has been introduced, though many more should be possible; the interaction techniques explored in [4] may be candidates.

Stone(Tool) vs. skin. It is also interesting and worthwhile to consider the similarities and differences between tangible UIs and organic UIs. Although these two types of UIs overlap in many ways, the conceptual differences are clear. Tangible UI systems often use multiple physical objects as tools for manipulation; each object is graspable so users are able to use physical manipulation. Because these objects often have a concrete meaning (called physical icons, or "phicons") in the application, many tangible systems are domain-specific (tuned for a particular application). For organic UI systems, users directly interact with possibly curved interactive surfaces (such as walls, tables, and electronic paper) with no intermediate objects. Interactions are more generic and less application-oriented. This situation may be compared to real-world interaction. In the real world, we use physical instruments (tools) to manipulate something but prefer direct contact for human-to-human com-

Even ceilings may someday function as an information display.

munication (such as a handshake). Tangible UIs are more logical, or manipulation-oriented, whereas organic UIs are more emotional, or communication-oriented, though more real-world experience is needed for a rigorous comparison.

Other modalities for interaction. In organic UIs, hands are still the primary body parts for interaction. But we should be able to use other parts, as we do in our natural communications. Eye gaze is one possibility. Another is blowing, which is useful for manipulation because it is controllable while also conveying emotion during interaction; a technique developed in [6] determines the direction of a blow based on an acoustic analysis. The BYU-BYU-View system adds the sensation of air movement to the interaction between a user and a virtual environment to add reality for telecommunications by delivering information directly to the skin [9].

INTERACTION BETWEEN REAL WORLD AND COMPUTER

In the context of traditional human-computer interaction, the term "interaction" generally means information exchange between a human and a computer. In the near future, interaction will also involve more physical experience (such as illumination, air, temperature, humidity, and energy). The interaction concept is thus no longer limited to interaction between humans and computers but can be expanded to cover interaction between the physical world and computers. For example, future interactive wall systems will react to human gesture, be aware of the air in the room, and be able to stabilize conditions (such as temperature and humidity) in the same way a cell membrane maintains the stability of a cell environment. Interactive walls may also be able to control sound energy to dynamically create silent spaces. Even ceilings may someday function as an information display. In this way, future interactive systems may more seamlessly interact with and control our physical environments. **C**

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EMERGING DISPLAY TECHNOLOGIES FOR ORGANIC USER INTERFACES

The display as a rigid, rectangular matrix is giving way to more fluid notions: thin, flexible, tactile surfaces customized to form and space.

BY ELISE CO AND NIKITA PASHENKOV

Television screens and computer monitors are so ubiquitous in our daily lives that the notion of a "display" is almost inevitably linked to something rigid and rectangular. However, even as technology moves toward smaller and more portable devices, there is also a strong and growing interest in the physical, tangible reality of the things we interact with.

Here, we explore emerging display technologies, emphasizing their application in flexible and deformable devices that potentially take on any shape or form. In each case, the most important factor is how the technology is (or might be) adapted to integrate with an existing flexible substrate (such as a solid sheet of plastic or woven fabric). In this sense, the field of flexible displays is as much a matter of process innovation and materials research as it is a question of electrical or computer engineering.

Sometimes hailed as a successor to LCD technology, organic light-emitting diode (OLED) displays are based on organic polymer molecules that compose emissive and conductive layers of the display structure composited together through a form of printing. The layers are deposited in rows and columns that result in a matrix of pixels that

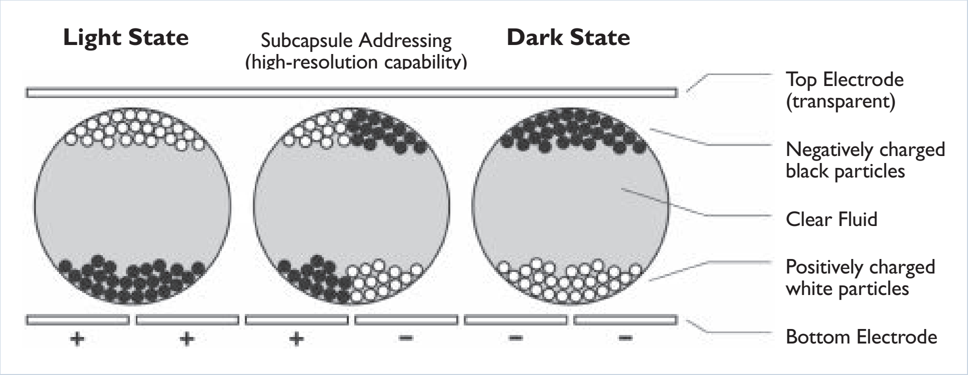

Figure 1. Principle of electrophoretic electronic paper displays.

emit light. Emissive OLED displays do not require backlighting and are viewable at oblique angles. They are also transparent; red, green, and blue layers can be stacked such that a full-color (RGB) pixel is a fully color-mixed single pixel with depth, rather than a closely spaced planar cluster of pixels as in traditional CRT and LCD displays.

OLEDs are commercially available today in a mass market of smaller displays (such as in car stereos, MP3 players, and cell phones). More innovative use of the technology awaits the streamlining of manufacturing methods; for example, flexible display screens are being developed using plastic substrates (such as thin polyester films and bendable metallic foils). Technology demonstrations by a number of companies, including Polymer Vision (polymervision.com), feature devices with rollable displays (see Figure 1). Taking the concept a step further, we anticipate development of large, flexible display interfaces that bend, flex, and conform to many surfaces.

OLED technology is also a focus of interest as a path to energy-efficient solid-state lighting. Since organic polymer layers can be manufactured as large-area active elements, it is possible to combine area color, shape, and flexibility to create novel interactive objects and interfaces. For instance, researchers at General Electric Global Research (www.ge.com/research/) anticipate light-emissive curtains and wallpapers.

Electrophoretic displays (EPDs), often associated with the brand name E-Ink (www.eink.com/), are marketed as alternatives to traditional flexible paper. One type of particle display, "electronic ink," consists of thousands of microcapsules deposited onto a substrate. Each microcapsule contains positively charged white particles and negatively charged black particles suspended in a clear fluid. When a negative electric field is applied, the white particles move to the top of the microcapsule, causing that "pixel" to appear white and vice versa (see Figure 1). The microcapsules are bi-stable, meaning that once configured as black or white, no further energy is required to maintain their state. As with OLED, flexibility is achieved through the use of flexible substrates (plastic) and conductors (metal foil or printed conductive traces).

Applications of E-Ink are primarily as a paper substitute in traditionally monochrome paper-based media (such as signage and e-books) but also include irregularly shaped and flexible displays. For example, the Seiko Watch Corporation (www.seikowatches.com) has produced a limited run of unique watches based on a small, flexible E-Ink display. E-Ink also prototyped various color displays and demonstrated multicolor EPDs using color filters [2].

In addition to even newer technologies still being developed and refined, existing technologies offer some of their benefits in the form of displays or light-emitting materials. For example, electroluminescent lighting (EL) is a technology through which thin, flexible lamps are produced via an industrial printing process. A layer of phosphor is sandwiched between two conductive layers, illuminating when an alternating electrical current is applied across the layers. EL is widely used in backlighting applications for portable electronics, as well as for large-surface-area applications. Manufactured EL panels can be cut into irregular shapes, as well as printed onto, lending themselves to advertising and signage.

At www.aeolab.com, we have applied the materials and processes used in the manufacturing of commercial electroluminescent panels to hand-print custom-designed light panels on paper and fabric within a studio environment. The Puddlejumper raincoat (www.mintymonkey.com/puddlejumper_p1.html) developed by Elise Co features EL panels silk-screened onto flexible fabric and activated via water-droplet sensors printed with conductive inks (see Figure 2).

In addition to flat panels, EL lamps are also manufactured as wire elements and packaged in clear plastic tubing of varying diameters. In this form, the material is well-suited to creative manipulation as a fiber, combined with other materials or integrated directly into textiles with either a woven or knitted structure. Artists and designers have used EL wire to make light-emitting artifacts ranging from garments to lamps to spatial installations (such as Loop's Sonumbra (www.loop.ph), a net-like illuminated canopy.

Optical fiber is another product that can be used creatively as a material for lighting and display. Specially treated "side-emitting" fibers (with outer coatings that diffuse light along the length of the strand rather than reflecting it perfectly within the interior core) are produced in thicknesses of up to a quarter of an inch. Strands of such fiber are woven into fabric and embedded into other materials, then coupled with light sources at the fiber ends to create unique textile and flexible-display surfaces. These integra-

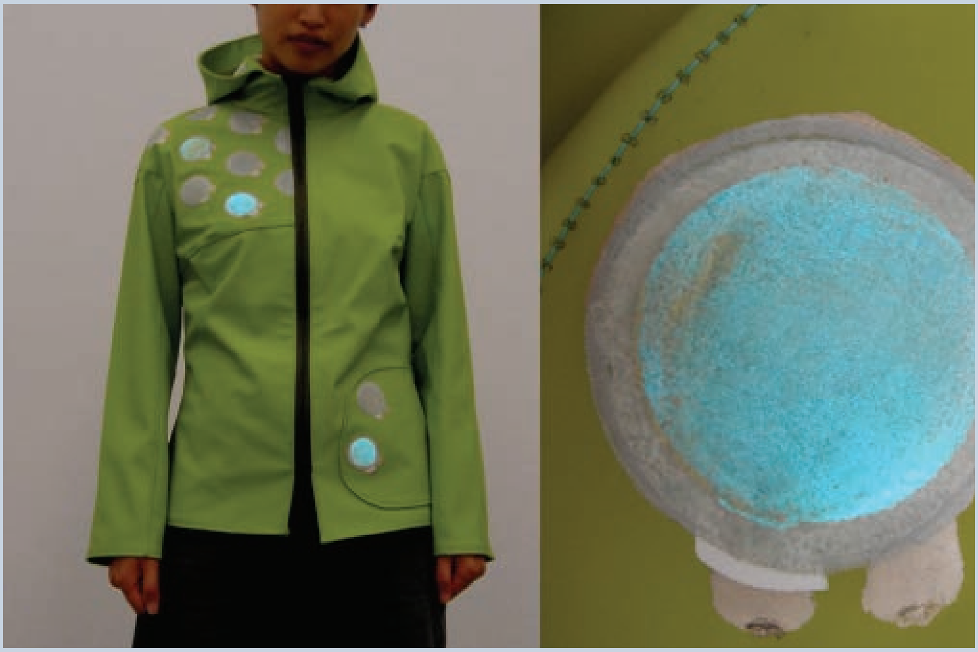

Figure 2. Electrolumine scent panels silk-screened onto flexible fabric on the Puddlejumper raincoat light up in response to rain.

tion techniques are also applicable to standard (end-emitting) fibers, resulting in small points of light rather than glowing lines or strands.

Discrete light-emitting diode (LED) lights are also used to create active surface topologies. Although LEDs are not inherently flexible, their small manufacturable size and simple circuitry means they can be dispersed over a flexible substrate. ColorKinetics, Inc. (www.colorkinetics.com) and Element Labs (www.elementlabs.com) offer products that incorporate LEDs into collapsible bendable matrix configurations and flexible strands. Others embed matrices of LEDs in flexible substrates that can be curved, formed to a surface, and even used as a wearable material. Lumalive technology from Philips Research (www.lumalive.com/business/) features fabrics and clothes embedded with LED matrix displays constructed in this fashion.

Innovative display interfaces are not limited to light-emitting sources. Alternative active materials (such as thermochromic inks that change color with temperature) can be used to construct novel display surfaces. A number of artists and designers, including International Fashion Machines (ifmachines.com) and XS Labs (www.xslabs.net), have used these inks as overprints on top of textiles that incorporate conductive spun threads. When a current is applied to the textile, resistive heating activates the printed ink and initiates a color change. Heating and cooling the metal filament manipulates the color of the textile-display over time [1]. As with the other examples we've outlined here, even the relatively limited behavior of such a system can be parlayed into a sophisticated multichannel output device through creativity of process and craft.

CONCLUSION

The practical application of flexible displays to particular user scenarios appears to be strongest in the fields of product, military, and fashion design. Flexibility or perhaps elasticity is inherently desirable for anything worn on the body. The tactile properties of soft and malleable surfaces also make sense in myriad design and interactive environments. What is interesting about the general domain of nonrigid displays is that so many aspects of design and engineering converge to generate displays that are also materials. From them we can imagine displays that curve to fit any space or form, flex to accommodate motion, and deform in response to physical interaction. Rollable or foldable displays for portable devices, large-scale interactive surfaces, and textiles with integrated displays in turn permit the design of user interfaces that are physically, as well as conceptually, flexible. **C**

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ORGANIC USER INTERFACES: DESIGNING COMPUTERS IN ANY WAY, SHAPE, OR FORM

Displays on real-world objects allow more realistic user interfaces.

BY DAVID HOLMAN AND ROEL VERTEGAAL

Today's computers can process information at incredible speeds, and have the flexibility to store and display data in many different forms. But when we compare the things we can do with the actual shape of these computers with the things we can do with that of other real-world tools, it seems a lot is lost. For example, a simple piece of paper, while holding graphical or written information, can be folded into most any shape, wrapped around products, or torn into bits and recycled entirely. Try doing that with your Blackberry.

The chief reason for the limitations of today's computer shape is the rigid planar structure of its LCD screen. The requirement to fit and protect the LCD, keyboard, and electronics causes the laptop computer to be rigid too. In this article, we argue that this planar rigidity in interface design generally limits the usability of our computers, in terms of their possible affordances.

A world of design around us is filled with "blobjects" [7]: tools with curved forms. Organic shapes are employed by the likes of Karim Rashid and Frank Gehry, who aptly apply materials like rubber, plastics, and even curved sheet metal in their designs. The first property that appears missing in computer displays, then, is the ability to


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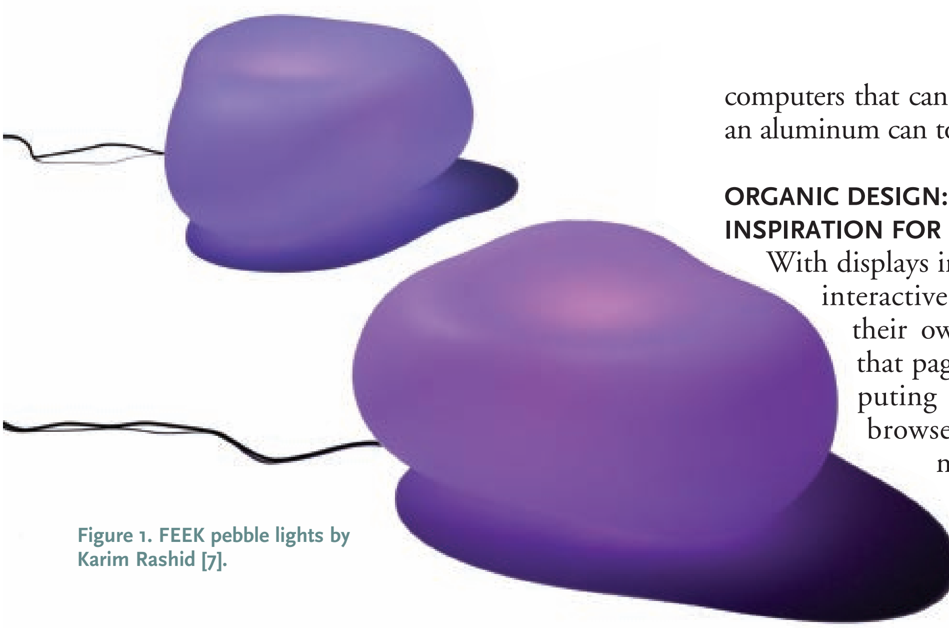

Figure 1. FEEK pebble lights by Karim Rashid [7].

have any organic shape, for example, curved like the light fixtures in Figure 1. There are clear advantages to the use of such displays, such as when working with curved data sets, like 3D models or geographical information. Another missing property is deformability. While fashion designers like Yves Saint Laurent take deformability for granted, it is not at all common in human-computer interactions. Yet deformability eases many real-world tasks, like storing things, or reading this magazine article, for example. The page flip is, in fact, a wonderfully effective way of navigating documents. Its affordance and ability to open a document at a random location is not easily mirrored by a mouse click. Deformability also allows tools to adapt their functionality to different contexts: a newspaper can serve information equally well as fish. Clearly, this kind of shape-shifting flexibility is not found in your average e-book reader.

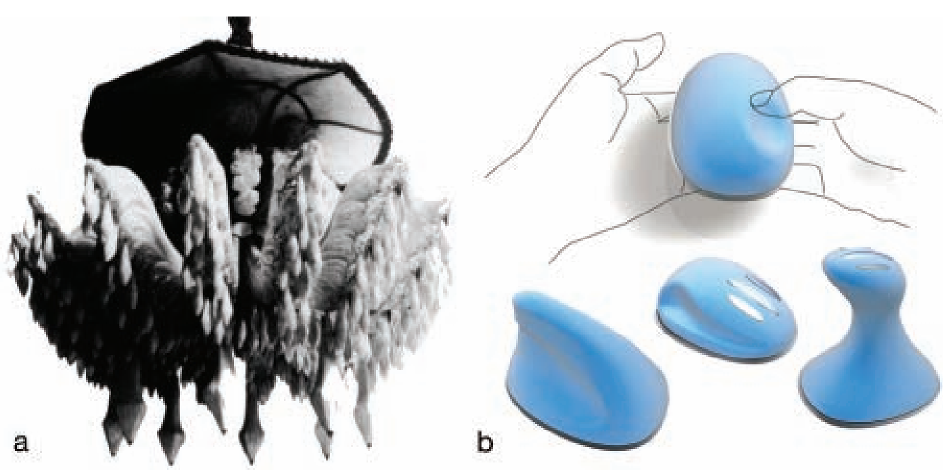

Figure 2. (a) Chandelier with jelly morphology (C. Roux, circa 1907); (b) Concept moldable mouse with jelly anatomy (Lite-On, 2007).

But might it one day be? New materials, such as E-Ink and Organic light-emitting diode (OLED) displays by Polymer Vision and Sony not only mimick the high contrast but also the deformability of paper, potentially making flatland interfaces a thing of the past. Interaction designers and researchers around the world are starting to work alternate, virtually analog, degrees of input. This design stream aims to develop computers that can take on any shape or form: from an aluminum can to a Lumalive jacket.

ORGANIC DESIGN: NATURAL MORPHOLOGIES AS INSPIRATION FOR INDUSTRIAL DESIGN

With displays in any form will come a wealth of interactive blobjects that literally shape their own functionality. E-book readers that page down upon a flick of the computing substrate. Beverage cans with browsers displaying RSS feeds and movie trailers. When pondering the design space of such future blobject computers, the anatomies and morphologies of biological organisms form an interesting source of inspiration. Natural organisms almost exclusively rely on flexible materials and non-planar shapes. For example, the leaves of plants form resilient solar panels that bend rather than break when challenged. They are not just flexible to adapt to their environment, they also grow and adjust shape to maximize solar efficiency. Computers may one day do just that.

Haeckel's *Art Forms in Nature* [1] was one of the first catalogues to celebrate organic morphologies. The book, which came out in 1904, was an instant hit with designers protesting modern industrialist art. Art Nouveau designer Constant Roux even used one of Haeckel's plates on invertibrate morphologies as an inspiration for a chandelier (see Figure 2a).

ORGANIC ARCHITECTURE: BALANCING INDUSTRIAL WITH NATURAL DESIGN

Haeckel's radiolarians also inspired Art Nouveau architect René Binet's entrance gate to the 1900 Paris World Expo. But within 10 years, the forces of industrialism would supersede Art Nouveau with their engineering aesthetics. Only in 1939 would American architect Frank Lloyd Wright challenge the Modernist perspective, coining the term Organic Architecture [3] to capture a new philosophy promoting a better balance between human and natural design. His most famous work, Fallingwater in Pennsylvania, still stands as one of the great triumphs of American 20th century design. With Fallingwater, Lloyd Wright did not intend to copy nature, like his Art Nouveau predecessors. Instead, he created a perfect harmony between the aesthetics of nature and those of modern architecture. Its concrete cantilevers, suspended over the ever-changing flows and rocky outcroppings of the waterfall over which they were built, allowed Wright to literally balance the planar geometries of modernity with the irregular flows of natural design. Having resided in Tokyo, Lloyd Wright's aesthetic was perhaps inspired by Japanese design philosophies like wabi-sabi, which emphasize natural imperfection and impermanence over Western controlled planar perfectionism.

TANGIBLE AND UBIQUITOUS: EMBEDDING COMPUTERS IN THE NATURAL WORLD

Indeed, what might computers look like if they were designed with a little more wabi-sabi? More curved, like a piece of earthenware, more flexible, like a sheet of Japanese Washi rice paper and more delicate, like handmade knitware? Perhaps a good start would be something like PingPongPlus, one of a string of Tangible User Interfaces designed by Hiroshi Ishii's research group at the MIT Media Lab in the mid-1990s. Ishii was one of the first scientists to design computers that were completely integrated into the user's natural ecology. His goal was to reduce the computer's heavy demands on limited-capacity focal attention of users, in favor of faster, high-capacity, peripheral channels of perception.

PingPongPlus was a table tennis table featuring a video projection of water, along with a school of fish. Whenever the ping-pong ball hit the table, its position would be sensed using microphones. A hit caused the water projected on the table surface to ripple on the spot, and the virtual fish to scatter. The combined use of projection on a planar surface, with natural objects tracked as input, allowed tangibles to seamlessly integrate computer elements in a physical game, without affecting its speed or physicality. Tangibles allowed for a tighter coupling between input and output, or, as Ishii more aptly put it: between bits and atoms. However, tangibles lacked the ability to display directly onto most input objects (such as the ball), as rigid displays are difficult to integrate into non-planar objects. They also lacked the ability to track multi-touch coordinates on the surface of such objects. And because their shape was not actuated, consistancy between bits and atoms could not always be maintained. As a consequence, tangible designs focused largely on the use of objects as devices for input.

ORGANIC USER INTERFACES: DESIGNING COMPUTERS IN ANY WAY, SHAPE, OR FORM

Some key developments in computing are now changing this equation. First, advances in flexible input technologies, like Jun Rekimoto's capacitive SmartSkin, now allow for any surface to sense two-handed, multi-finger touch. Jeff Han's computer vision multi-touch displays changed the way designers think about the connection between input and output. Tovi Grossman took input into a different dimension altogether. His use of ShapeTape, optical fibers that sense bending, eased 3D drawing through direct representation of shape. Something is different about input today, with Nike marketing shoes with accelerometers that sense the pace for iPod beats. In Italy, Danilo De Rossi is sewing piezoelectric sensors into clothes that monitor vital functions, and keep their wearer healthy. And in 2007, Lite-On designers won the red dot award for their concept jelly input blobjects that can be molded to fit the hand (Figure 2b).

The second development is that of so-called electrophoretic ink (E-Ink for short) at MIT. E-Ink, now a Massachusetts-based company, designs displays that behave much like printed paper. E-Ink displays reflect light directly from their environment, and as such are much more energy efficient than LCDs. E-Ink allowed companies such as Philips to start pondering the design of flexible polymer display substrates. The Philips spin-off Polymer Vision has demonstrated Readius: the first smartphone with a foldable electrophoretic display. Much like a paper scroll, this display can be rolled up into the body of the phone. Last February, Sony unveiled its first full-color flexible Organic LED display, the size of a wristwatch. And at CES 2007 Philips Research introduced Lumalive, a display made of tiny LEDs that are woven into the fabric of clothing.

The most remarkable development, however, is that of shape-changing materials inspired by organic compounds found in plant and animal life. Materials such as shape memory alloys, which mimic the behavior of muscles, are used to create interactive knitware that is responsive to environmental stimuli. Smaller actuators mean computing devices can now be built that adjust their shape according to some computational outcome, or depending on interactions with users. This

Figure 3. Exploring molecular strain in Senspectra.

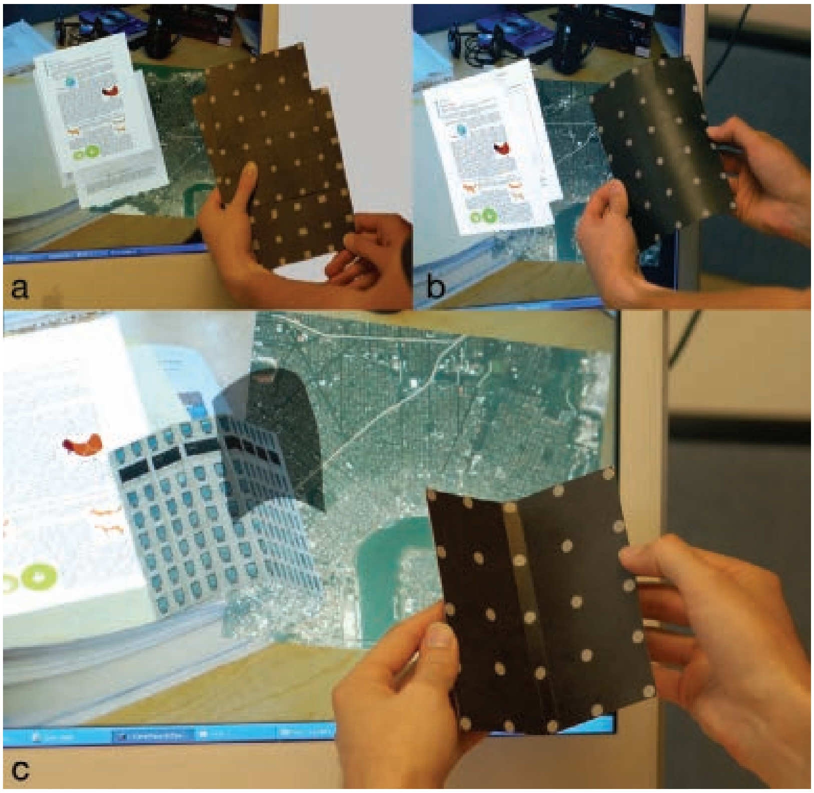

Figure 4. Some possible interactive shapes for paper computers: (a) Organizing window sheets in a stack; (b) Leafing through window sheets; (c) Folding window sheets into three-dimensional content.

will eventually result in displays that are not just volumetric, but that flexibly alter their 3D shape.

Together, the three developments mentioned here allow for a new category of computers that feature displays of almost any form: curved, spherical, flexible, actuated, or arbitrary. E-Ink displays will first find widespread use in e-books, mobile appliances, and advertising. With cost coming down, a logical next step would be curved or flexible displays on products like bottles, boxes, furniture, sportswear, and toys. How will users interact with such oddly shaped displays? What will their user interfaces look like? One thing is clear: they will look very different from the ones we use today. Rather than relying on planar GUIs, they will feature more *organic* user interfaces.

Defining Organic User Interfaces. "An Organic User Interface is a computer interface that uses a non-planar display as a primary means of output, as well as input. When flexible, OUIs have the ability to become the data on display through deformation, either via manipulation or actuation. Their fluid physics-based graphics are shaped through multi-touch and bi-manual gestures." OUIs aim to support a number of design goals that transcend traditional usability. Their learnability, for example, is governed by the clarity of their affordances, and by their ability to adapt these to new contexts of use. With their emphasis on flexibility and user satisfaction, OUIs inspire users to be creative rather than merely productive. OUIs also promote well-being through diversity of posture and ergonomic fit. Although OUIs should be designed for sustainable use, they need not necessarily be made out of organic materials for their interface to still be considered organic. In 1989, British architect David Pearson formulated it as follows [4]:

"Let the design:
be inspired by nature and be sustainable, healthy, conserving, and diverse;
unfold, like an organism, from the seed within;
exist in the 'continuous present' and 'begin again and again';
follow the flows and be flexible and adaptable;
satisfy social, physical, and spiritual needs;
'grow out of the site' and be unique;
celebrate the spirit of youth, play and surprise;
express the rhythm of music and the power of dance."

These words inspired the following three principles for OUI design.

Figure 5. Paperwindows: A prototype paper computer.

This describes well what Organic User Interfaces excel at: the physical representation of activities. Picking up a display activates it for input. Rotating it changes view from landscape to portrait. Likewise, bending the top right corner of the display inward may invoke a paging down action, while bending it outward pages up. Bending both sides inward causes content to zoom in, while bending outward zooms out. An example of such behaviors is found in Parkes' Senspectra, a molecular modeling toolkit (see Figure 3). When a user bends the molecular model, LEDs embedded in the nodes glow according to the amount of strain exerted upon the optical fibers that connect them.

Form Follows Flow. Today, more than ever, meaning is appropriated by context. Similarly, OUIs adapt their form to better suit different contexts of use. Their shape fluidly follows the flow of user activities in a manifold of physical and social contexts of *re*use, as well. A simple example is found in the use of folding in clamshell cellphones. Opening the clamshell activates the phone, a very strong affordance indeed. Closing it ends its functionality, deactivating the keys, protecting the display and reducing its footprint, all in one movement. A more profound example is found in the Readius: its display folds out when needed, thus doubling the available screen real estate when the activity such requires. Like clothing, forms should always suit the activity. Clothing fits the body while closely following its movements, and can even be deformed to serve other functions, like holding objects, if necessary. Thus, if the activity changes, so should the form. This kind of adaptation is best exemplified by actuated OUIs like Lumen [6], a display that changes shape in 3D, or by SensOrg, an electronic musical instrument with a flexible arrangement of inputs that are molded to varying physical or creative demands [10]. The Moldable Mouse in Figure 2b shows how malleability also reduces the risk of painful repetitive strain injuries. Its body—made of non-toxic polyurethane-coated modeling clay with stick-on buttons—allows input to literally follow the shape of the hands.

Input Equals Output. In a GUI, input devices are distinct and separable from output devices: a mouse is not a display. However, this separation is typically not true for interactions with physical objects. Paper documents may be stacked, moved around, and folded with a kind of physical immersion that can only be dreamed of in GUI windows. This immersion can only be achieved through a complete synergy between multi-finger, two-handed manipulations and corresponding visual, haptic, and auditory representations. This means displays should sense their own shape as input, as well as all other forces acting upon them. In an OUI, such input is not distinguishable from its graphic output: users literally touch and deform the graphics on display. As such, OUI displays render as a real-world object, into the shape that best supports data interpretation. Bits and pieces of such behavior are already found in Apple's rigid planar iPhone display: its multi-touch screen, for example, senses the deceleration of the finger, providing an impulse to the physics engine to scroll the menu as if it was flicked.

Function Equals Form. According to Lloyd Wright's mentor, Sullivan, the shape of a building or object should be predicated on its intended function, not its precedent: "form follows function." Bauhaus popularized his credo by abolishing embellishments in everyday design. Lloyd Wright thought this was a mistake: according to him, form should not follow function: "they should be one, joined in a spiritual union." This notion resonates with Gibson's ecological approach to visual perception, embodied in the concept of affordance: the qualities of an object that allows a person to perceive what action to take. That is, the form of an object determines what we can do with it.

EARLY EXAMPLES OF ORGANIC USER INTERFACES

One of the first systems to exhibit OUI properties was the Illuminating Clay project [5]. Bridging the gap between TUI and OUI, it was the first interactive display made entirely out of clay. With their hands, users could deform the clay model, the topography of which was tracked by an overhead laser scanner. The scan served as input to a 3D landscape visualization, which was then projected back onto the clay surface. Illuminating Clay illustrates the blurring between input and output device: Users could, for example, alter the flow of a river by molding valleys into the clay. Here, function is also triggered by form, which literally follows the flow of interactions.

Gummi: Flexing Plastic Computers. Another early envisionment of an OUI was Gummi [8]—a pressure-sensitive PDA that simulated a flexible credit card displaying an interactive subway map. Bending the display would cause this subway map to zoom in or out, while a touch panel on the back would allow users to scroll. Again, function equals form: the shape of the display affords zooming, and the interplay between haptics and visuals reinforces this functionality. (For more information, see Carsten Schwesig's article in this section).

Paper Computers. Books and paper also form powerful sources of inspiration for flexible computer design. Paper is particularly versatile as a medium of information. According to Sellen and Harper [9], users still prefer paper over current computer displays because it makes navigation more flexible. Paper input is direct, two-handed, and provides a rich synergetic set of haptic and visual cues. Paper supports easier transitions between activities by allowing users to pick up and organize multiple documents two-handedly. Paper is also extremely malleable: it can be folded—a primary source of input when constructing models—or bent, most often applied in navigation. Paper can be randomly arranged, or in stacks, and can even contain other objects. With the development of flexible E-Ink displays we can imagine that in the future our computers will be indistinguishable from a sheet of paper. One of the questions we have been trying to answer is how will we interact with such flexible computers?

We experimented with the use of Foldable Input Devices (FIDs) for GUI manipulations by tracking the shape of several cardboard sheets that featured retroreflective markings (see Figure 4). Behaving like real paper documents, 3D graphics windows follow the shape of associated FIDs. When FIDs are stacked, so are the window sheets in the GUI (Figure 4a). Stacks of window sheets are sorted with a shake and browsed by leafing action (Figure 4b). Using a special FID, window sheets can even be folded into threre-dimensional models, further blurring the distinction between a window sheet and its content (Figure 4c).

Inspired by Wellner's DigitalDesk [11], Paperwindows [2] was the first computer made entirely out of three-dimensional sheets of paper (see Figure 5). It simulated a flexible, high-resolution, full-color, and wireless E-Ink display of the future.

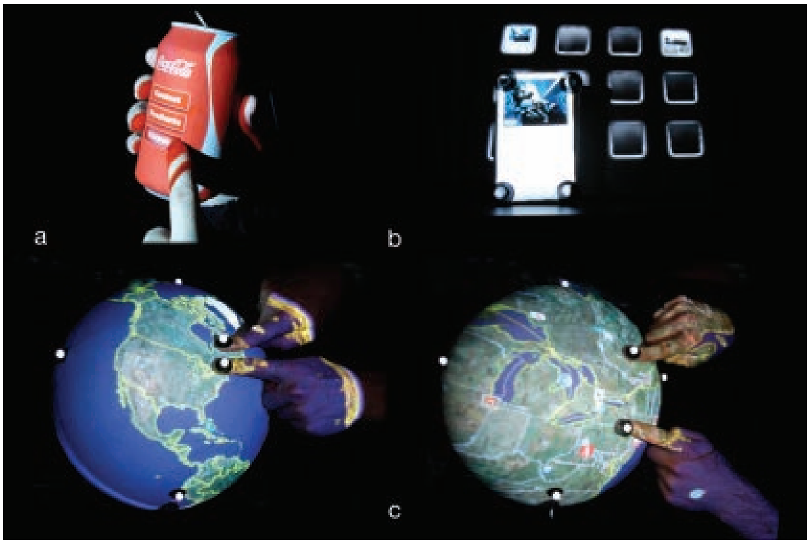

Figure 6. Interactive Blobjects: (a) Dynacan computer with flash animation; (b) iPod form factor on an interactive cardboard design bench; (c) Zoom gesture on spherical screen with Google Earth.

Paperwindows are regular sheets of paper, augmented with eight retroreflective markers. These markers allow a Vicon to capture the motion and interactive shape of the paper, which is modeled as a non-uniform rational B-spline (NURBS) surface textured with the real-time content of an application window. When projected back onto the paper, the 3D models correct any projection skew caused by paper folds, giving the illusion the paper is, in fact, an interactive print. We experimented with a Web browser of which most functions were accessible through changing the shape of the paper—the primary display of the computer. Bending the sheet around its horizontal axis would cause the Web browser to page down or up. Bending the document back around its vertical axis would cause the Web browser to go back or forward in its browsing history. Fingers were also tracked: a link was clicked by touching it. A paper window was activated by picking it up. Information could be copied from one document to the next by rubbing two windows onto each other. Documents could be enlarged through collation, and sorted by stacking. Such physical interaction techniques remove any distinction between input and output: in paper windows the shape, location, and

The examples described here only scratch the surface in terms of ways in which we might interact with future computers of any shape or form.

orientation of the display *is* the primary form of input.

From Interactive Blobjects to Curved Computer Interactions. In the Interactive Blobjects project, we are today exploring opportunities afforded by marrying everyday objects with oddly shaped displays through tracking and projection. For example, Dynacan, the dynamic beverage can shown in Figure 6a, is an early prototype of a fully recyclable curved computer. Its display features Flash animations, videos, and RSS feeds. Future versions will be made of flexible full-color E-Ink, powered by a processor and battery pack inside the can. Users can scroll by rotating the can, which is sensed by a set of accelerometers. Electronic components can be made detachable prior to recycling the can. Dynacan is part of a larger workbench investigating OUI design. Figure 6b shows how any piece of cardboard, curved or a cube, can simulate a computer interface. By selecting dials, menus, and interactive skins from a palette of interaction styles (shown in the background) a simple cardboard box is turned into a fully functional iPod. Press a finger on the palette and the iPod becomes a fully functional iPhone instead. More complex blobjects are also possible, like architectural cardboard models with live animated textures, or interactive spherical displays, like the Google Earth browser in Figure 6c.

CONCLUSION

The examples described here only scratch the surface in terms of ways in which we might interact with future computers of any shape or form. Possibilities include computers with displays that are curved, flexible, and that may even change their own shape in order to better fit the data, or user for that matter. In Organic User Interface design, these computers will no longer be conceived of as distinguishable from the world in which they live. All physics acting upon displays, including their shape, will be used to manipulate information. Functions will be triggered through form changes that follow the flow of the ever-changing world of the user. In a world where multi-tasking is increasingly common, the chief purpose of an OUI is to interweave a plurality of highly contextualized, interspersed activities across a variety of disconnected contexts. One challenge will be for it to do so in a manner that carries consistency across activities and contexts. Rather than a single OUI acting as an advanced Swiss army knife, users need to utilize the OUI that comes in the form most appropriate for a particular activity. Flexibility should not be misinterpreted as "one OUI fits all": it is exactly in celebrating the diversity of display shapes that a wealth of OUI designs will find their purpose.

In the not-so-distant future, curved, full-color, flexible LEDs, OLEDs, or E-Ink displays will appear in our homes, furniture, e-books, jewelry, and clothing. When tired of the color of your suit, the pattern of your wallpaper, or the interface on your cellphone, you simply download a new one from an online store. Some hardware interfaces may one day be monitized like software entirely, substituting the wasteful trend of buying new atoms with that of more eco-conscious bits. That would be a final frontier in the design of computer interfaces that turns the natural world into software, and software into the natural world. **C**

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SUSTAINABILITY IMPLICATIONS OF ORGANIC USER INTERFACE TECHNOLOGIES: AN INKY PROBLEM

BY ELI BLEVIS

The moment you decide sustainability is an issue with respect to interaction design and the design of interactive devices is the moment you realize how complex the business of deciding what to actually do about it is. It is not just a simple matter of calculating the energy and environmental costs of manufacturing, use, salvage, and disposal of one technology over another.

For example, it was long ago claimed that computing technologies would create a paperless office—a claim that is not yet in sight. Many people print things rather than read on screen—they like to hold paper in their hands and mark things up. Ever since I acquired a portrait mode capable LCD monitor, I have mostly stopped printing things. I can now read and write an entire page of text on my 1200x1600 pixel screen at 140% the size it would be if I printed it. As a result, I almost never print anything anymore. The environmental costs of the energy used to power my display must be weighed against the costs of printing the page when I am just reading, assuming that I would actually power-off my display when I am reading what has been printed. Furthermore, the environmental cost of production of the portrait mode display and the environmental costs of the premature obsolescence and disposal of the display I had before this one are also part of the equation.

Environmental costs are not very static—increasing demands for a technology can drive down some such environmental costs while increasing some others. Nonetheless, Organic UI technologies, such as digital paper or flexible displays and E-Ink technologies offer promising potentials for the development of sustainable practices in interaction design. Each of these potentials has dangers of inducing unsustainable behaviors as well.

One potential is due to an advantage of paper display technology itself. No energy is used when reading an E-Ink display owing to the bistability of the material—that is, digital paper preserves its state each time it is updated without the need for additional power. From the perspective of environmental sustainability, this seems to be a more important feature than the issue of the present environmental cost of making "a sheet of" digital paper, since such costs will change dramatically with improvements in the technology and with production on a larger scale.

A second potential is related to the concept of books as durable objects. When it becomes possible to create a book using the new digital paper that can be turned into any book by means of an electronic update, the potential for a more sustainable medium presents itself—one that does not require the cutting of trees. But, the durability of the digital paper book can only match that of the ordinary notion of a book if the other attributes that make ordinary books enduring objects in general are also matched or even exceeded.

A third potential is based on the possibilities for making displays that are more portable, cheaper, smaller, and more pervasive. From a sustainability point of view, pervasive, small, inexpensive displays may be an advantage to the degree that they build an infrastructure of modularity. If upgrading a display on an interactive device such as a cell phone, PDA, MP3/video player, or laptop becomes as viable as upgrading the storage capacity of a device by substituting a memory card such as an SD card, this could have the effect of making digital artifice last longer. On the other hand, if the possibility of making more portable, cheaper, smaller, and more pervasive displays ends up driving a practice of even more disposability and premature disposal due to frequent obsolescence with respect to display devices—for example, on product packaging—the consequences could be devastating from an environmental point of view. Even if the substrates are made of recyclable materials, recycling is not as environmentally sustainable as reuse. And, if the substrates are not made of recyclable or biodegradable materials, the effects on the e-waste stream may possibly augment the toxicity of the present-day e-waste stream [3]. In any event, the negative social impacts of adding to the e-waste stream and even of certain recycling practices are also a global sustainability issue [1, 2].

For digital paper to be better than ordinary paper from a user experience point of view, it will need to properly address at least these four interactivity issues: resolution—the quality of the text will need to be as good or better than paper; control—the use of digital paper and labels will need to be as easy and straightforward in use as ordinary paper and labels; portability—digital paper will need to be as portable or more portable than ordinary paper at the same resolutions; authenticity—the experience of using these displays will need to be as aesthetically authentic and tangible as holding a physical piece of paper. If these user experience concerns can be adequately addressed together with some of the other concerns described here, the potentials of organic display technologies to enable choices for a sustainable future can be realized.

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DESIGNING KINETIC INTERACTIONS FOR ORGANIC USER INTERFACES

Considering the future of kinetic design in user interfaces.

BY AMANDA PARKES, IVAN POUPYREV, AND HIROSHI ISHII

We are surrounded by a sea of motion: everything around us is in a state of continuous movement. We experience numerous and varied kinds of motions: voluntarily motions of our own body as we walk; passive motion induced by natural forces, such as the rotation of windmill blades in the wind or the fall of a leaf from a tree due to the force of gravity; physical transformations such as the growth of a flower or the inflation of balloon; and the mechanical motion of the machines and mechanisms that populate our living spaces.

It is hardly surprising then that humans have always been perplexed and fascinated by the nature of motion. In 500 BC, the Greek philosopher Parmenides declared that all motions are an illusion. Experimental and theoretical studies of motion by Galileo and Newton have laid the foundation of modern physics and modern science; and Einstein's general theory of relativity has explained movements on a cosmic scale.

Perhaps more than trying to understand motion, however, humans have always been fascinated with producing artificial motion. While developments of machines that transform energy into mechanical motion, in particular steam engines, underpinned the industrial revolution of the late 19th century, it was the development of

moving pictures that most convincingly demonstrated the power of motion as a communication medium. Since then, the use of motion as a communication medium has been mostly limited to the rectangular screens of movie theaters, TVs, or computer displays. Several research directions have attempted to take moving images from the screen into the real world, such as Augmented Reality (AR) and ubiquitous computing. However, the underlying paradigm has hardly changed: the screen may change location—moving images can be projected on the table—but the objects they display to the user and their motion remain essentially virtual.

Recently, however, there has been a rapid increase in interest toward using physical kinetic motion of real objects as a communication medium. Although the roots of this interest stretch back as far as the 18th century to early work on automata, the recent emergence of new "smart" materials, tiny motors and nanomanipulators, organic actuators and fast networked embedded microprocessors has created new and exciting opportunities for taking motion out of the screen and into the real world. Instead of simulating objects and their motion on screen, we attempt to dynamically reshape and reconfigure real physical objects and perhaps entire environments to communicate with the user.

Figure 1. (a) Giacomo Balla's *Velocità e Vortice (Speed and Rotation)*; (b) Laszlo Moholy-Nagy's *Light-Space Modulator* (replica at the Van Abbe Museum, Eindhoven, image courtesy HC Gilje); (c) OuterSpace.

Kinetic interaction design forms part of the larger framework of Organic User Interfaces (OUI) discussed in the articles in this special section: interfaces that can have any shape or form. We define Kinetic Organic Interfaces (KOIs) as organic user interfaces that employ physical kinetic motion to embody and communicate information to people. Shape-changing inherently involves some form of motion since any body transformation can be represented as motion of its parts. Thus kinetic interaction and kinetic design are key components of the OUI concept. With KOIs, the entire real world, rather then a small computer screen, becomes the design environment for future interaction designers.

There are several reasons why KOIs are exciting and different from previous interaction paradigms. Fundamentally, KOIs exist in the real world that surrounds us. Creating environments that can seamlessly mix computer-generated entities with the real world has been one of the most important research directions in recent history. For example, AR systems dynamically overlay real-time 3D computer graphics imagery on the real-world environment allowing users to see and interact with both physical and virtual objects in the same space [10]. Unlike in AR interfaces, however, with KOIs, all objects are real and therefore perfectly mixed with both living organisms and inanimate objects. Merging the computer interface with the real world, means it can be a significantly more intimate and organic, with the computer interface being an organic part of our environment. In addition, unlike virtual images real physical motion can communicate information on several perceptual levels, that is, real physical motion can stimulate not only visual, but also aural, tactile, and kinesthetic sensations in humans. This allows creating much richer and effective interactions than what has been previously possible. Finally, human beings possess a deeply rooted response to motion, recognizing innately in it a quality of "being alive" provoking a significantly deeper and emotional response from users.

This article presents a framework for this emerging field of kinetic interaction design. We discuss previous work that provides the foundation of motion design in interaction as well as analyze what can be learned and applied from relevant theories and examples in robotics, kinetic art, and architectural systems. We also discuss some of the current directions in kinetic interface designs and conclude by proposing principles that can be applied in the future design of such interfaces and forms. Described as "one of the 20th century art's great unknowns," the language of movement has been an underutilized and little-examined means of communication, and the use of motion in human computer interfaces is still in its infancy. This article offers a broader perspective of the possibilities of kinetic interaction design, taking advantage of motion as a medium for creating user interactions befitting the 21st century.

KINETIC PRECEDENTS: LEARNING FROM AUTOMATA, KINETIC ART, AND ROBOTS

Human beings have a rich history of designing and utilizing kinetic forms in art, automata, and robotics, from which we can draw inspiration and analysis of the possibilities for kinetic interaction design. In particular, the 17th century marked a significant increase in the phenomena of human or animal automatons, that is, self-moving machines. One of the most famous of these was a mechanical duck by Jacques de Vaucanson. The duck was described as a marvel that "drinks, eats, quacks, splashes about on the water, and digests his food like a living duck." Another similarly spectacular automaton from this period was The Writer by Pierre Jacquet-Droz: with internal clockwork mechanics, this life-size figure of a boy could write any message up to 40 letters. The interesting characteristic of these early automata was that they were not utilitarian in nature, but were constructed as highly technological decorations to be observed and enjoyed. They reflected the early human fascination with simulating human characteristics in machines and in particular with our ability for self-initiated motion.

In the early 20th century Italian Futurists explored motion as a primary means of artistic expression, looking at motion as a "concept." While the Futurists did not create mechanical kinetic devices, they were the first to investigate the concept of motion and speed as a plastic expressive value and the first to create an artistic vocabulary based on motion. Paintings such as Giacomo Balla's *Speed and Rotation* (see Figure 1a), a Futurist work from 1913, represent "an expression of time and space through the abstract presentation of movement."

The 1920s produced the launch of what is considered "kinetic art," works that featured real physical movement in three-dimensional space. Artists such as Laszlo Moholy-Nagy, Alexander Calder, and Nicholas Takis experimented with creating sculptures whose parts were moved by air currents, magnetism, electromechanical actuators, or spectators themselves. The aim of these kinetic artists was to make movement a central part of the art piece, where motion itself presented artistic and aesthetic value to the viewer (see Figure 1b). These early kinetic works show the strong aesthetic value of physical motion. These aesthetics are being explored today by such artists as Sachiko Kodama, who creates organic kinetic sculptures based not on physical objects but on magnetically actuated fluids; her work is described in an article in this issue.

Moving into contemporary times, the field of social robotics and robotic art offers a rich motion vocabulary both in the functional and perceptual areas. While some projects, such as the robotic dog Aibo, have attempted to simulate animal or human forms and movements, others attempted to design an independent and unique motion vocabulary to communicate with the user. For example, OuterSpace [6] presents a reactive robotic creature resembling an insect antenna that is flexible enough to explore the environment (see Figure 1c). Outerspace appears as a playful, curious creature exploring the surrounding space looking for light, motion, and contact. As Outerspace engages with an observer, its motion patterns, based on body language and human gesture, change in response to stimulus and contact, engaging the observer in a social interaction. Although abstracted, Outerspace's organic motion repertoire allows the user to perceive a sense of intelligence in the creature, changing the nature of the interaction.

These examples from early automata to kinetic art to social robotic creatures demonstrate how reactive kinetic motion designed to be mimetic of a living organism has the power to engage us, fascinate us, and create an interactive conversation with an otherwise disembodied object. It is our innate ability as human beings to be engaged by the lifelike qualities of motion, allowing us to employ the movement of objects as a tool for communication and engagement, and allowing inanimate objects to become partners in our interactions.

KINETIC DESIGN FOR HUMAN-COMPUTER INTERACTION

The examples in robotics and kinetic art have demonstrated how motion in a self-actuated entity

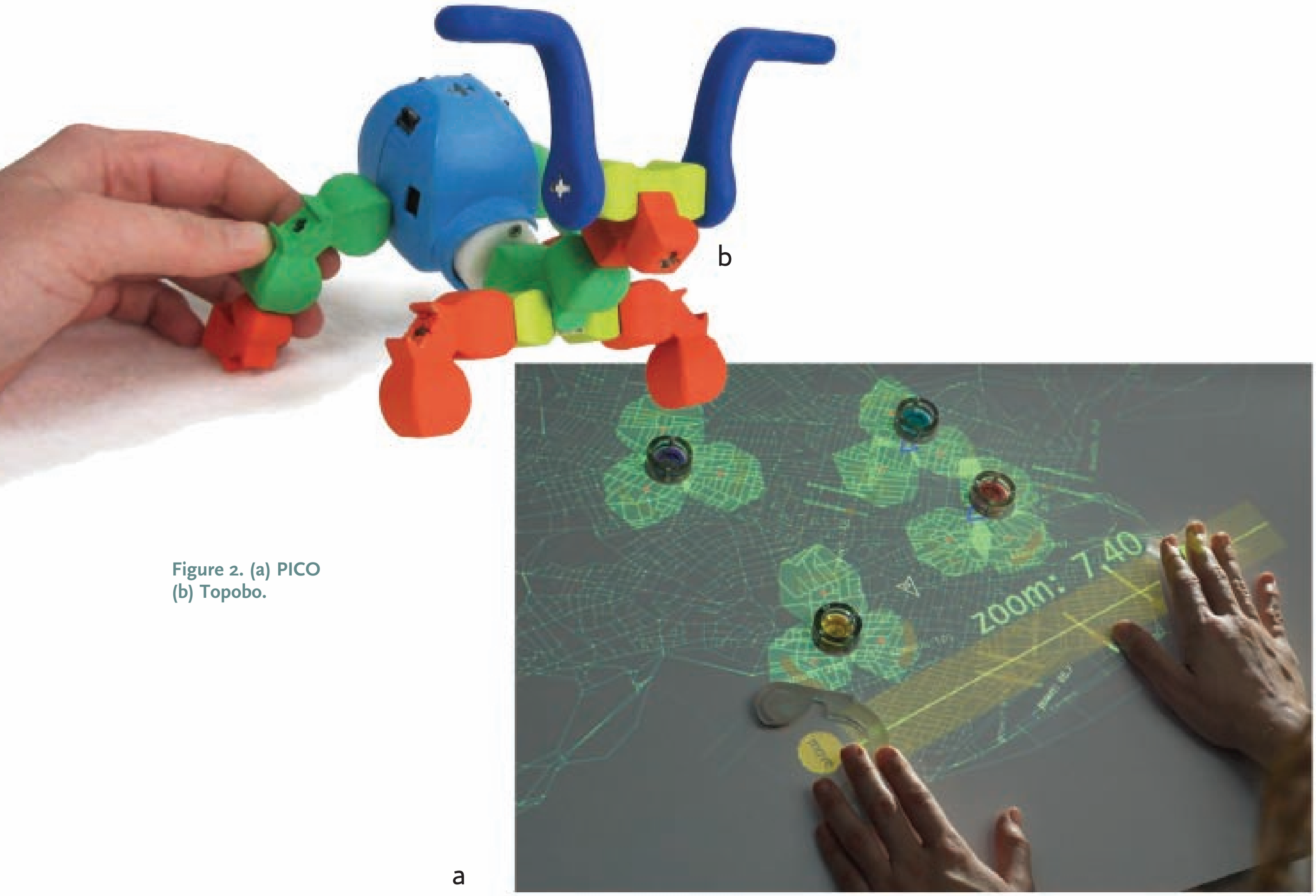

Figure 2. (a) PICO (b) Topobo.

can be used to engage and communicate. Here, we continue to explore how such motion constructs can be applied for designing user interfaces, in other words, if we imagine that the entire world around us can deform itself in response to our actions, then what kind of user interface experiences and new productivity tools could become possible?

A growing number of projects in interface design have laid the groundwork for discussion of kinetic design. Some of the important early exploration has been conducted in the field of Tangible User Interfaces (TUI) [4] and ambient user interfaces projects such as Pinwheels and Ambient Fixtures [1]. Within tangible interfaces, however, the coupling between the physical and the digital has usually been in one direction only: we can change vital information through physical handles, but the digital world has no effect on physical elements of an interface. Adding elements of kinetic design establishes bi-directional relationships in TUIs significantly expanding their design and interaction vocabulary.

The kinetic interfaces concept, however, is broader than the TUI paradigm: our inspiration partially comes from one of the earliest visions of computer-controlled kinetic environments suggested by Ivan Sutherland, a pioneer of interactive 3D computer graphics and virtual reality. In 1965 he speculated that the ideal, Ultimate Display would be " … a room within which the computer can control the existence of matter. A chair displayed in such room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet … would be fatal" [12]. Although manipulating matter on the molecular level, which would be required for such an Ultimate Display, is currently impossible, the Ultimate Display proposes a way of thinking about KOIs as a new category of display devices that communicate information through physical shape and motion. In a sense, every instance of kinetic design discussed here can be considered an early and crude approximation of the Ultimate Display applied to a specific application.

Basic Phrases of Motion. In KOIs, motion can be delineated with physical components that are actuated in a way that can be detected by and respond to the user. There are millions of kinds of motion; however, most of the motions in KOIs can be represented by describing spatial motion of individual elements of the kinetic interface. These motions can be perceived not only visu-

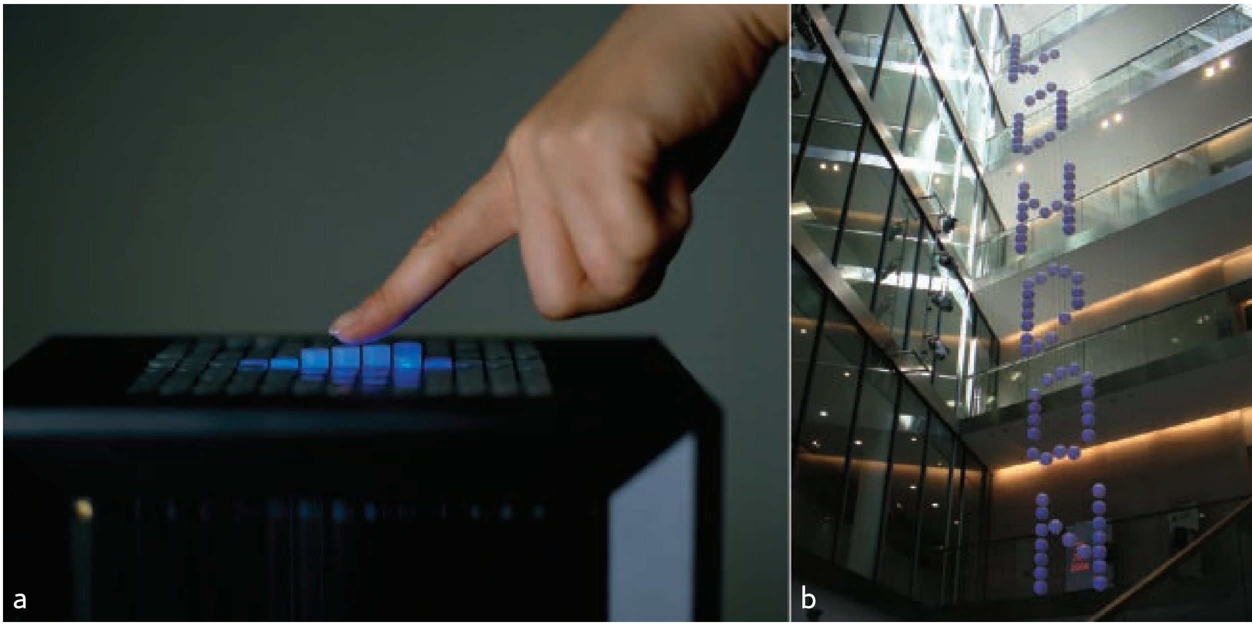

Figure 3. (a) Lumen (photograph by Makoto Fujii, courtesy *AXIS* magazine); (b) *The Source.*

ally, but also haptically (through physical contact) or aurally, since moving objects may produce sound. Therefore, the basic vocabulary of kinetic interface design includes speed, direction, and range of the motion of interface elements, which can be either rotational or linear positional movement. The forces that moving objects may apply to the user or other objects in the environment are another important design variable. Finally, the physical properties of interface elements, such as surface texture or surface shape can also be controlled and used for interaction. These define a very elementary vocabulary for interaction designers that can be used in creating kinetic interaction techniques.

Here, we discuss some of the approaches in designing kinetic interactions and illustrate the discussion with examples of several systems that have been developed. The overview is not intended to be an exhaustive survey of the current state in Kinetic Organic Interfaces, but rather categorize and indicate some of the directions of future development. As the field matures new concepts and applications will certainly appear.

Actuation in Dynamic Physical Controls. The first category of KOIs is the most straightforward application for actuation in user interfaces: dynamically reconfigurable physical controls. For example, PICO [8] and Actuated Workbench [7] use an array of electromagnets embedded in a table to physically move the input controls: pucks on a table top (see Figure 2a). The pucks can also be used as input devices. The important property of such interfaces is that they allow for maintaining consistency between the state of underlying digital data and the physical state of interface controls. In one application the system is used for computing locations of cell phone towers; when the layout of towers was recomputed, the corresponding pucks physically move to reflect the new configuration.

Kinetic physical controls provide one possible solution for an important interface design challenge: how to create interfaces that are simple, yet provide sufficient functionality to control complex problems. In the kinetic approach used in PICO, controls can be provided "on demand," simply adding them when needed, with the system repositioning elements according to the current state of the system. Another approach is to create physical controllers on the fly by modifying the shape of the control surface: this approach is investigated in shape-shifting kinetic displays that we discuss later.

Actuation as Embodiment of Information. As a communication medium, motion of elements in a KOI can be used to embody representations of data or changes in data. In static form, such an interface need not contain information, it is purely its kinetic behavior that communicates with the user. This approach has been investigated in ambient displays projects—displays communicating digital information at the periphery of human perception [4]. A classical example is the Pinwheels [1] project where a stream of data, such as stock market activity monitoring, is mapped to the motion of a set of pinwheels, speeding up clockwise if the markets are increasing, for example. Pinwheels exist purely as ordinary non-computational objects; it is only their motion, such as speed and direction, which allows them to become communication devices.

Another important use of kinetic motion for infor-

FUTURE OF TRANSFORMABILITY

Today's digital objects and systems are layered with functionality, which presents a new challenge for designers: how can forms subscribe to multiple functionality while maintaining a simplicity in user interaction that clearly describes their functionality? In current products, multi-functionality is usually maintained at the expense of ergonomics or ease of use. Kinetic programmability in interface design may offer a method to address this, in the form of physical transformability. A kinetic surface or skin, or a transformable internal structure can be linked to computational data sensed from the object's use (gestural or positional controls) or the surrounding environment and the physical form of the object changes in response, making objects physically adaptable to their function or context. No longer does form follow function, form becomes function. While the current state of shape-changing objects may be relegated to the science fiction of *Transformers*, advances in shape memory materials and nanotechnology are bringing cutting-edge experiments to life.

mation communication can be found in haptic user interfaces: devices that allow users to feel information through tactile or kinesthetic sensations. This is can be achieved by applying forces that restrict user finger, hand, and limb movement, such as in force-feedback interfaces, or by mechanically stimulating user skin in tactile user interfaces. Haptic interfaces have been extensively investigated in virtual reality and telepresence applications, to allow users to feel objects properties, such as resistance, weight, and surface texture. Recently, haptic interfaces have been used in desktop and mobile interfaces, allowing users, for example, to feel information on a touch screen with their fingers. Although haptic user interfaces have a long history, past research has been primarily focused on the specifics of producing and understanding haptic sensations. In KOIs we take a much broader approach that looks to explore the use of kinetic motion on multiple perceptual levels, including haptics.

Actuation as Embodiment of Gesture. An emerging class of KOIs record motion and gestures directly from the human body and replay them creating a sense of a living organicism. For example, Topobo [11] is a 3D constructive assembly with kinetic memory, the ability to record and play back physical motion in 3D space (see Figure 2b). By snapping together a combination of static and motorized components, people can quickly assemble dynamic biomorphic forms like animals and skeletons. These constructions can be animated by physically pushing, pulling, and twisting parts of the assembly. Topobo components can record and play back their individual motions, creating complex motion behavior in the overall structure of a creation. Importantly, the kinetic recording occurs in the same physical space as it plays back: the user "teaches" an object how to move by physically manipulating the object itself. This provides an elegant and straightforward method for motion authoring in future kinetic interactions.

Actuation as Form Generation. Perhaps one of the most inspiring categories of kinetic interfaces is that of devices and displays that can dynamically change their physical form to display data or in response to user input. Such displays have been often referred to as shape-shifting devices. One approach in designing such self-deformable displays is creating kinetic relief-like structures either on the scale of table-top device, such as in Feelex [5] and Lumen [9] (see Figure 3a) or on the scale of the entire buildings, such as in Mark Goulthorpe's Aegis Hyposurface. An alternative approach is illustrated by *The Source* installation [3] that allows direct creation of low-resolution 3D shapes hanging in space. It consists of 729 balls suspended on metal cables forming a 9x9x9 spatial grid, where each ball is a "pixel" (see Figure 3b). By moving on the cables, the balls can form letters and images floating in space.

Shape displays explore the possibilities for how physical transformability can embody the malleability so valued in the digital realm (see the sidebar here). They communicate information by manipulating 3D physical shapes in real time that can be either seen or felt by hand. The information can be communicated not only by creating a physical shape but by modifying or rearranging existing shapes, such as in case of claytronics robots (self-reconfigurable robots), under development at Carnegie Mellon University [2].

TOWARD A DESIGN LANGUAGE FOR KINETIC ORGANIC INTERFACES

The preceding examples of Kinetic Organic Interfaces have demonstrated a variety of methods to incorporate kinetic behavior as a valuable strategy in interface design. However, they have barely scratched the surface of the possibilities we see available in this relatively untapped arena. As designers and HCI scientists begin to explore the language of motion more fully, we now discuss some of the salient design parameters and research questions to consider when utilizing kinetic motion in interaction design.

Form and Materiality. In order to recognize and comprehend motion, it must be embodied in a material form. Hence, a crucial and little-understood design parameter is how properties of materials and forms affect motion perception and control. A very significant perceptual shift can occur with a change in material and forms—a jerky disjointed motion of a series of mechanical motors can be embedded in a soft padded exterior and the perceived quality of motion can be inversed to a smooth oscillation. Understanding the material affordances, their interaction with the user and other objects, environmental light and sound is crucial in designing kinetic interactions.

Kinetic Memory and Temporality. While computational control allows actuated systems to provide real-time physical feedback, it also offers the capability to record, replay, and manipulate kinetic data as if it were any other kind of computational data. We refer to such data as kinetic memory, an idea introduced earlier by Topobo [11]. The concept of kinetic memory opens new and unexplored capabilities for KOIs; for example, objects can fast-forward or slow down motion sequences, move backward or forward in time; or the objects can "memorize" their shape history and share them with other objects.

Repeatability and Exactness. We can easily distinguish artificial motion because of its exact repeatability. In designing kinetic interactions, repeatable exactness is the simplest form of control state, and in many behaviors it is easily identifiable. Introducing a level of variation in kinetic interfaces or perhaps even "noise" can add a degree of an organic natural feeling, usually missing from direct digital actuator control.

Granularity and Emergence. During the period of 1772–1779, Swedish engineer Kristofer Polhem created a series of small wooden objects describing basic mechanical elements for motion design: a mechanical alphabet. It consisted of 80 letters each demonstrating the simple movement that is contained in a machine, for example, translating rotary movement into reciprocating movement. If this principle of dissecting form and mechanics into single elements—kinetic phrases—is combined with contemporary digital control structures, new materials, and actuators, it becomes possible to imagine a system where a kinetic behavior could be designed both concretely and formally. This would allow a designer to easily merge kinetic elements into user interfaces as well as everyday objects, living and working environments.

Inventing such basic "grains" of motion in kinetic interactions also brings up the issue of emergence. Emergence, defined as the process by which a set of simple rules determine complex pattern formation or behavior, creates systems that contain elements that are thoroughly comprehensible to understand individually (like ants in an ant colony), while it is difficult to understand the overall behavior of the system functioning with decentralized control. Designing for emergence, KOIs may create systems that could someday reflect some of the complexity of living organisms.

As we move into the 21st century, it is clear that our relationship with motion needs to be reconsidered. The new class of emerging Kinetic Organic Interfaces is a step toward creating that change. The rapid development of new technologies, such as piezo motors and plastic actuators polymers, will potentially allow for creating efficient and inexpensive interfaces that can be used in applications for communication, information presentation, style, and decoration, as well as many others. Developing such applications requires stepping outside of the boundaries of classic HCI domains and combining expertise from robotics, haptics, design, and architecture. The work in Kinetic Organic Interfaces is still in its infancy, and we consider this article as an invitation for discussion on the future of kinetic design in user interfaces and as stimulus for further research in this exciting and emerging area. C

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WHAT MAKES AN INTERFACE FEEL ORGANIC?

BY CARSTEN SCHWESIG

Movies can make us forget that we are sitting in a cinema among strangers, looking at images projected onto a wall. Instead, we feel as though we are observing real people in real situations and we become emotionally involved in the narrative. User interfaces can trigger a similar suspension of disbelief: we forget we are operating a machine to manipulate virtual, digital data. Instead, we experience media and applications as part of our physical environment. Such interfaces feel "natural," or rather "organic."

Figure 1. Gummi interface prototype showing map navigation.

Used in this sense, the term "organic" refers to subjective experience. It is therefore difficult to define or quantify, but we can observe some qualities that make interfaces feel organic. Here, I focus on techniques that achieve this effect by introducing physical properties to the user interface.

User interfaces can incorporate elements of physics in a number of ways: one approach is to imbue real physical objects with digital properties, as in the work of the Tangible Media Group at the MIT Media Lab. Another approach is to simulate physical environments on screen: some car racing games, for example, derive much of their appeal from convincing physics modeling. But physics—real or simulated—can also be very limiting: computers are so useful as a media platform precisely because digital media are not bound by the laws of physics (hypertext links break when printed on paper; YouTube is incompatible with the real or simulated physics of film projectors).

Organic interface design represents a less literal approach which, rather than focusing on physical objects or metaphors, emphasizes the analog, continuous, and transitional nature of physical reality and human experience. By combining sensitive analog input devices with responsive graphics, we can create user experiences that acknowledge the subtleties of physical interaction.

By using analog sensors in input devices, continuous and subtle changes in physical interaction can be measured.

A ubiquitous example of analog input coupled with responsive graphics is the computer mouse: continuous mapping of physical hand movement to virtual pointer position results in the experience of direct manipulation that is central to the WIMP interface. The introduction of the mouse, in combination with a responsive screen interface, transported digital information from the abstract, cerebral world of the command line right into our tangible, physical environment.

The use of analog sensors was explored in the development of the Gummi interface concept [1]. Gummi was inspired by a new generation of organic, flexible electronics. The underlying reasoning was that, at some point in the future, it would be possible to build credit-card sized, flexible computers composed of layers of organic electronic components: flexible batteries, circuits, sensors, and a flexible organic light-emitting diode (FOLED) display. What kind of new interfaces would be possible with such a hypothetical device?

The resulting interface concept and prototype allows users to browse digital media by a combination of physical deformation and 2D position control. Held in both hands, the device can be bent along one axis while a touchpad mounted on the back of the device is used to control 2D position. With a simple, consistent vocabulary of physical interactions, it is possible to navigate file structures, maps, hyperlinks, photo albums, and movies. We also implemented a street map that can be scrolled with the touchpad and zoomed by bending the device (see Figure 1). The flat prototype can be bent either away from or toward the user to control zoom direction (see Figure 2). The amount of bending is mapped to zoom speed: slight deformation results in a slow, continuous zoom; stronger bending increases the zoom speed. This kind of analog interaction has two benefits. It gives the user finer control over the feature in question and it feels organic because it is as sensitive to the nuances and transitions of physical interaction as a real-world object.

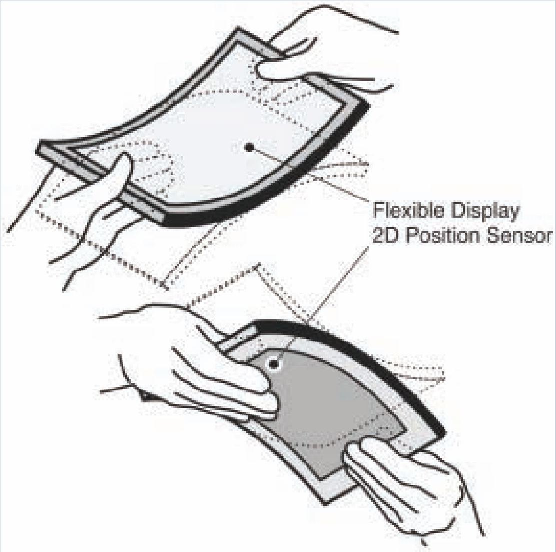

Figure 2. Gummi device and interaction.

Although Gummi was inspired by new hardware technology, the use of analog sensors in the resulting prototype became a focus for the project. We realized that capturing analog, continuous physical interaction led to an interface that offered interesting new functional possibilities, while at the same time feeling very organic.

Two recently released products feature analog interaction techniques. The Nintendo Wii gaming platform includes an input device that adds hand and arm gestures to the interaction vocabulary of game interfaces. Apple's iPhone represents the first mass-marketed product that uses multi-touch interaction. Its responsive graphical user interface incorporates subtle, animated visual behaviors that add up to create a very tactile, organic user experience.

Analog interaction techniques arguably played an important role in the success of both the Wii and the iPhone and recent technological developments suggest there is a lot of room for exploration in this area: small, inexpensive sensors can capture a wide range of analog physical inputs such as gestures, pressure, deformation, multi-point touch, orientation, and location. New materials, such as organic LED displays, point toward flexible computers that can sense their own shape. Mobile devices with fast processors and high-resolution displays support graphical user interfaces that can match the subtle, analog nature of physical interaction.

The examples mentioned here share a number of characteristics that contribute to the organic feel of these interfaces: by using analog sensors in input devices, continuous and subtle changes in physical interaction can be measured. The analog complexity of input is reflected in a highly responsive graphical user interface, featuring smooth animation and consistent visual behavior. As a result, the input device and graphical user interface are experienced as a whole, not as independent elements of the interface. The cumulative effect of these characteristics is a user interface that inspires a suspension of disbelief: intangible information feels as though it is part of our tangible physical environment. **C**

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INTERACTIONS WITH PROACTIVE ARCHITECTURAL SPACES: THE MUSCLE PROJECTS

Developing structures as flexible networked information processors.

BY KAS OOSTERHUIS AND NIMISH BILORIA

Modernist architecture, from Le Corbusier to Herzog de Meuron, is based on an outdated aesthetic, one that leans heavily on that of mass production. In architecture, however, we can no longer celebrate the beauty of repetition of similar elements. Although critics may think differently, even current deconstructivists, like Morphosis and Gehry, base their aesthetic essentially on ideas of mass production: they start from series of mass-produced components, for which they subsequently make many exceptions. They create holes in volumes, they cut off, they chamfer and twist, they superimpose, they collage: they build in conflicts as they try to individualize components.

ONL and Hyperbody design for the Digital Pavilion in South Korea depicting the interactive environment that acts as an interface between users (players), real structures, and augmented virtual environment.

At ONL, an architectural design firm in Rotterdam, The Netherlands, and the Hyperbody Research Group at the TU Delft in The Netherlands, we have been designing an entirely new aesthetic, one based on the principles of customization. Mass customization of buildings means that all produced building components have a unique identity and are individuals that can be addressed independently. Each building component is different, and fits only in one place. The structure that is built becomes a giant 3D puzzle, where each piece fits exactly in one location, and the unique ID of each component is comparable to an IP address of a computer linked to the Internet. This new generation of Pro-active Architecture (ProA) is based on customization that respects the individuality of each component, building up a completely new aesthetic. ProA buildings are responsive to the individuals that live inside them, and to their environment. In the ProA concept, buildings are organic, ever-changing vehicles for processing and displaying information. They exhibit independent real-time behaviors, like adjustments in shape in response to changing environmental circumstances such as wind direction.

At Hyperbody, we have instigated a series of interactive prototypes to study the design of such buildings. For the NSA exhibition in Centre Pompidou in 2003, we were invited by the curators to build a first installation, NSA Muscle. NSA Muscle is a proactive inflated space, its surface populated with a mesh of 72 muscles, all of which were addressed individually. In the installation, the muscles cooperated as a swarm of muscular actuators, so as to behave in real time. The NSA Muscle danced, hopped, twisted, contracted, and responded with subtle movements to sensor input coming from visitors touching particular locations on the nodes of the muscular mesh. The paradigm of ProA was created, appearing on the cover of the French daily newspaper *Libération*.

Our first truly interactive environment was the Saltwaterpavilion, realized in 1997. A weather station positioned at the North Sea sent data to a computer running Max/MSP, which informed a mixing table to produce a soothing massage of light and sound that refreshed every 20 seconds. The public could interact with this dynamic environment using a sensorboard, pushing and pulling lights and sound toward both extremes of the interior space (see Figure 1). Interactivity and architecture were designed from scratch with similar high budgets and at the same scale. Interactivity formed an integral part of the architecture for the first time in the history of architecture. Imagine if we could produce a swarm of such Waterpavilions, all

Figure 1. Sensorboard in Saltwaterpavilion.

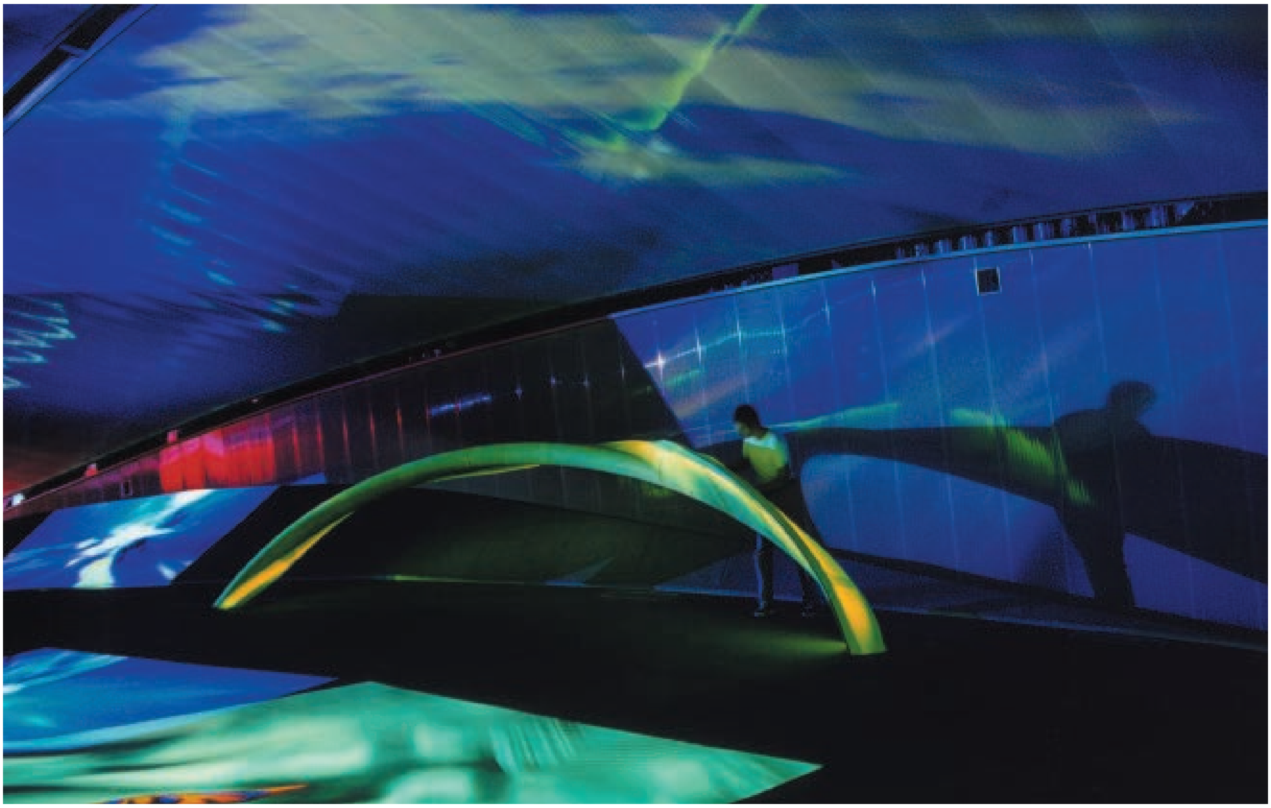

Figure 2. Hylite panels actuated by embedded fluidic Festo Muscles.

placed on different locations around the globe, all exchanging information with each other, with their local environment, their local users, and with their global directives. What would these ProA buildings tell each other, and what sort of information would they exchange?

THE MUSCLE PROJECTS

With the Muscle projects, our first prototypes of ProA, we tried to emphasize the real-time actuated spatial response that a building or architectural space might provide. The prototypes were conceived of as a collection of 3D spatial strips, programmed to respond to their occupants through proximity and touch sensors, processors, and actuating fluidic muscles made by Festo (see Figure 2). Each strip is made out of Hylite panels, a sandwich material with combined properties of aluminum and plastic that is bendable. Two fluidic muscles produce compression power that transforms the otherwise hard-edged strip into soft luxuriant undulations.

In the Muscle project, the cumulative coupling of basic units gives rise to three distinct elements: a responsive floor, a ceiling, and walls joined together in a closed 3D loop. These elements are linked in space in a highly interdependent manner, constantly exchanging information (such as air pressure varia-

By introducing interactivity, we wanted to break the stereotype of the facade of a building as a barrier separating the interior from the external environment.

Figure 3. Muscle Tower 1.

Figure 4. The Muscle Tower 2.

tions), yet behaving as a collective whole to attain certain spatial reconfigurations.

THE MUSCLE TOWER 1

The Muscle Tower is a working prototype (model scale 1:20) for a building's structure that responds to external stimuli (the weather) and internal conditions (the users) (see Figure 3). This programmable structure is seen as a process relating to other running processes (people, the environment) that displays real-time behavior. It was first shown at the Aandrijftechniek exhibition, part of the Industrial Week (a meeting point for Dutch industry), at the Jaarbeurs Utrecht. This exhibition informed visitors about many of the latest innovations, developments, and ideas in the fields of power transmission, factory automation, and motion control in one brain-stimulating visit. Some possible practical applications of a real-time adaptive structure like the Muscle Tower include:

- Adaptive Facade: Adapting to changing external environmental conditions and internal usage patterns.
- Responsive Roof: Responding to changes in solar radiation.

The potential importance of interactivity through organic reshaping of buildings as computers, and as computer displays, has become apparent.

Figure 5. The Muscle Body.

• Pro-active Space: The building morphology augments itself in real time to suggest and provoke the possibilities of engaging with a space.
• Balancing Structure: Dynamically resisting external forces, making a skyscraper stand perfectly upright when enduring strong winds.

THE MUSCLE TOWER 2

The second Muscle Tower prototype was an interactive advertising billboard structure with built-in behaviors for reacting to its environment, through bending and rotation of its elements. The tower consists of a network of aluminum rods, connected flexibly to each other and to pneumatic muscles by means of hollow iron spherical nodes (see Figure 4). Each spherical node attaches to one end of a fluidic muscle and two aluminum rods that create 3D framed sections (of variable dimensions), which are stacked upon each other to build up the entire tower. This positioning of the muscles allows the 3D frame to be bent, twisted, and deformed while maintaining a sense of balance of the entire tower, thus preventing it from toppling over. A cumulative stacking and attaching of subsequent frames allows for a higher degree of movement. The tower is programmed using Virtools, which obtains data about the presence of people by means of a sensing field with motion sensors laid out in the periphery of the tower (see the sidebar). The tower can elegantly bend, twist, and turn toward the sensed spatial coordinates of people around it in order to attract attention to an advertisement displayed on the tower's surface.

Figure 6. A Bamboostic forest.

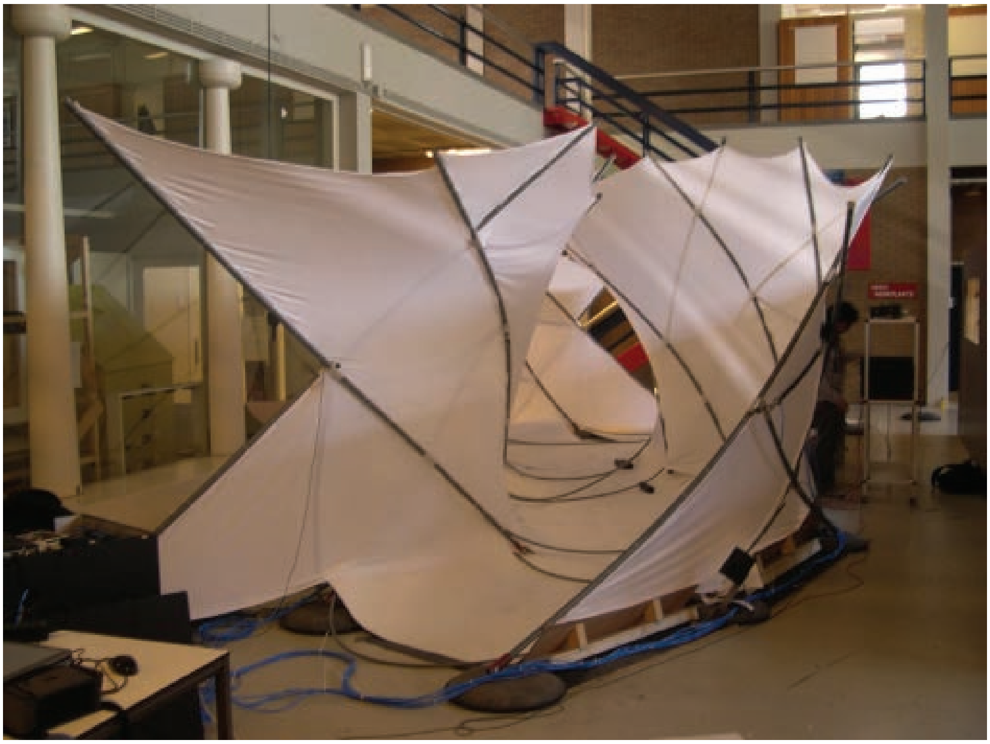

Figure 7. The Muscle Space.

THE MUSCLE BODY

The Muscle Body is a fully kinetic and interactive prototype of an interior space. The project is an architectural body constituting a continuous Lycra skin that makes no categorical distinctions between floor, wall, ceiling, or doors (see Figure 5). This continuous skin is structurally supported by a spiraling 3D PVC tube framework, thus endowing it with flexibility and stiffness. A total of 26 Festo muscles are integrated into this spiraling structure to control the physical movement. Using these materials, the Muscle Body can change its shape, its degrees of transparency, and the sound it generates in real time as it interacts with people who enter it. The translucency of its Lycra fabric varies according to the degree of stretching induced by this shape augmentation. The thin strips of light mounted between the tubing and the skin, in combination with the altering translucency of the fabric results in an intriguing play of light upon activation. There are also a number of speakers integrated into the skin that generate sound from several sound samples combined and transformed according to the actions, proximity, and movement of the people inside the Muscle Body.

THE BAMBOOSTIC

The Bamboostic installation is another example of an interactive architectural space (see Figure 6). It operates as an interactive forest that could be placed in a public space like a square, and is composed of a series of mechanical trees. These trees are the result of coupling three pneumatic muscles utilized for actuation with a central mast of bamboo specifically chosen for its flexibility. Steel strings, interconnected with three pneumatic muscles on the central bamboo post were woven through clamps and connected to the rigid base. Actuation of each individual muscle produced the conceptualized movement of the bamboo in predefined directions. After successfully building and testing one prototype, a series of trees was created and grouped together to create an organized forest of kinetic bamboo structures. The kinetic behavior is regulated in accordance with the proximity of people near each individual bamboo structure. Proximity is tracked in real time via a tracking system developed at Hyperbody using Virtools. The tree nearest to a tracked individual bends toward him or her, and its movement is replicated in a decreasing extent by surrounding trees. This produces a rather natural landscape feel via a set of mechanized entities.

THE MUSCLE SPACE

Figure 7 shows the Muscle Space project, an interactive passage space that interacts with passersby in a proactive manner. The structural profile chosen for the Muscle Space consists of double-curved surfaces that are actuated by pneumatic muscles woven into a grid of PVC tubes. The kinetic behavior displayed by this dynamic structure is a complex combination of scissoring, folding, bending, and falling movements. The floor surface of this interactive passage has embedded pressure sensors that register the movement of people passing by. These movement patterns are communicated to a set of behavioral algorithms which, in turn, coordinate the actuation of pneumatic muscles and ambient sound along the length of the passage. Passersby thus become passengers within an architectural body that is communicative and seemingly alive.

ACTUATED BUILDING TECHNOLOGIES

Pneumatic Entities: Fluidic Muscle Type MAS (provided by Festo): A flexible tube with reinforcing fibers in the form of a lattice structure for up to 10x higher initial force compared to a cylinder of identical diameter. The muscles tend to contract 20% of their initial length with the induction of air pressure, hence making it act as an actuating device to alter the node positions of the prototype.
Properties: Diameters 10mm, 20mm, and 40mm, rating length 30mm–9,000mm, no stick-slip effect, low weight, hermetically sealed.
Application: Actuating devices connecting the Hylite plates into a singular networked whole.

The Black Box (by ONL and HRG with Festo air valves and switching components): A hard-edged box housing the switching mechanisms: I/O boards connected to the 72 valves controlling the air pressure lock of the fluidic muscles. The box has provisions to attach the compressed air intake pipes through distribution channels; houses the CPU and power back-up mechanisms.
Application: Used as a secure container, housing the brain of the installation through which the fluidic muscles are instructed to attain the contraction or relaxation modes.

Flexible Skins:
Hylite panels: Hylite is a sandwich sheet comprising two thin aluminium layers with a plastic core in between. It was developed for car body parts. It integrates high flexural stiffness and extreme lightness. Compared to sheet steel with the same flexural stiffness (0.74 mm) and aluminium (1.0 mm), Hylite is 65% and approximately 30% lighter respectively. These results have been obtained by combining the best properties of aluminium and plastic in a single material. The Hylite panels were specifically selected for the skin of the prototype due to the flexibility criterion and the ease involved in its handling.
Lycra-based fabric: Lycra is a stretchable fabric often used for sports clothing. The translucency of the fabric varies according to the degree of stretching.
Application: Spatial envelope, interactive furniture surface, projection surface.

Control System: Sensing devices used to enrich the activity recognition criterion of the prototype. The selection of the sensors involved two basic distinctions in the manner in which we wanted data to be sensed: the global level—dealing with proximity of users with respect to the prototype; and the local level—dealing with finer adjustments made to the panels by means of individual inputs through touch sensors, hence providing partial control by the user.

Sensors: Proximity sensors for sensing the distance of the occupant from the installation and touch sensors for sensing the amount of pressure exerted upon a surface.

Software: Virtools Dev 3.0, software is used for developing an inherent connectivity between the sensed data and the expected behavior output from the prototype (by means of programming output rules for the system). The software is used as the main computation tool that receives inputs from the MIDI device (sensed data), processes data in accordance with the scripted behaviors programmed into it and sends output digital signals via PCI cards device, which are directly linked with actuating mechanisms.

The graphical scripts are systematically composed to communicate dynamic data, related with proximity of users (through sensors) to a set of arrays built into the software file, which act as the interface between the real and the virtual worlds. These arrays are constantly updated via the 'sensor reading script' developed at the HRG, which primarily utilize MIDI inputs for this purpose. Apart from this script, a parallel operation that concerns the status of each system unit (a component attached with the muscle) is tracked constantly in real time by means of updating the corresponding valve status linked with the pistons. These two operations formulate the so-called first-level operations of the scripts, which are aimed at capturing the context within which the prototype is embedded. The second level involves a 'data processing' script to check in parallel with the previously acquired information: the Status and the Sensor reading scripts, hence abstracting the change in context by means of reading the updated array and the current position status of each system unit. This information is gathered by means of compiling it in the form of genotypic numeric strings, which are forwarded to the Smart lab PCI cards.

The PCI cards, as mentioned earlier, further relate these numeric strings in correspondence with the airlock valves status and runs re-checks for any updated arrays in parallel to create a phenotype string, which involves a long numeric string equivalent to the number of pneumatic muscles in the prototype and represents the new on, off status commands by means of numeric 1 and 2 codes. This processed data directly communicates with the airlock valves and results in the opening and closing of valves corresponding with the numeric data delivered to the black box, hence actuating specific sets of pneumatic muscles to produce an appropriate system response. **C**

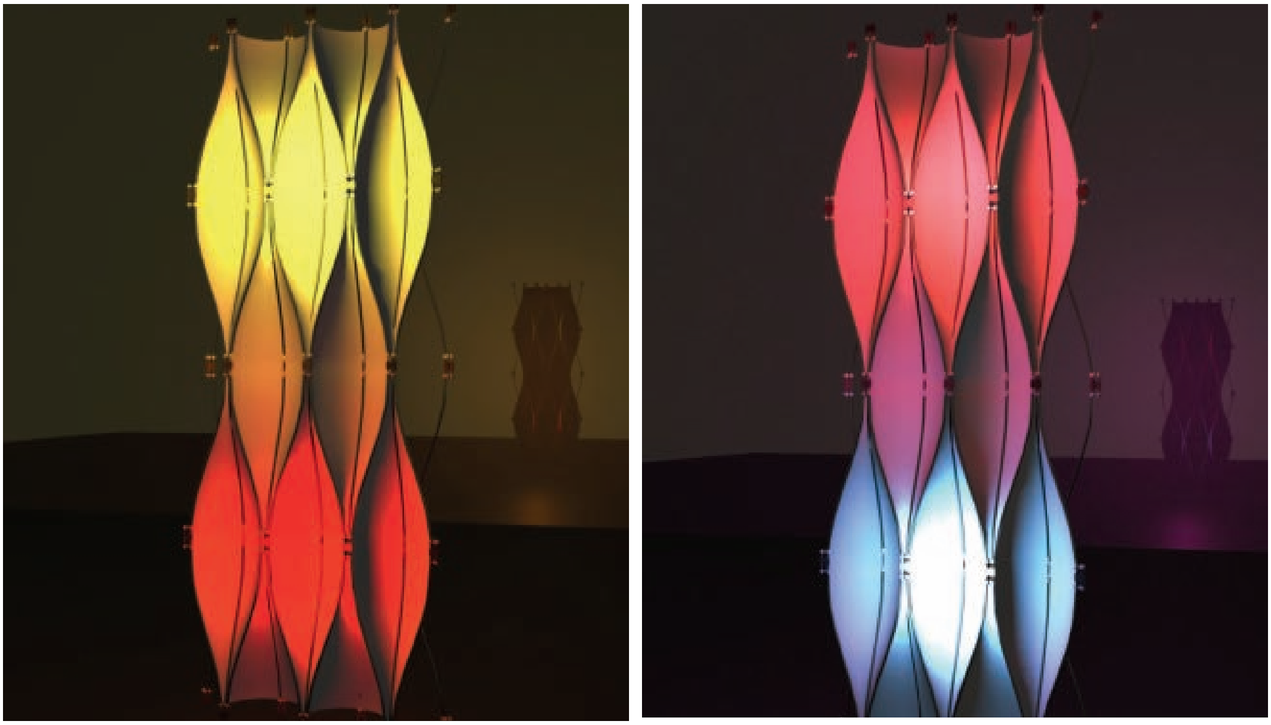

Figure 8. Muscle Facades.

THE MUSCLE FACADE

By introducing interactivity, we wanted to break the stereotype of the facade of a building as a barrier separating the interior from the external environment. The Muscle Facade (see Figure 8) moves and changes its visual appearance in accordance with fluctuating contextual conditions, such as the weather. The facade registers contextual information through a multitude of sensors and connectivity to global media (such as weather forecasts). This incoming data is processed by Virtools, and the Muscle Facade manifests its response by changing its own shape, the color of images projected on its surface, and the augmentation with sound.

CONCLUSION

Through the examples and experimentation described here, the potential importance of interactivity through organic reshaping of buildings as computers, and as computer displays, has become apparent. We realized that if we develop our buildings as flexible networked information processors, they become vehicles that can receive and transmit information to and from each other. Just like cars on the highway form a population of interacting moving bodies, just like houses in the city form populations, these interactive architectural bodies will form a network of live entities. All would feed on data produced by other buildings and elements, all would behave in real time, all would tell the others what they did, and all would become a self-learning entity. Self-learning capacity will only arise if the architectural body will be part of a swarm, if it can communicate with peers. Then they may start building up a body of knowledge, perhaps not unlike its human inhabitants. Our minds are completely helpless and uninformed if we do not communicate with peers. Our body of knowledge does not reside in any one brain, but is embedded and distributed across a network of brains and bodies. It will be no different with these architectural bodies, the brains of which will feed on meaningful data from the Internet and other wirelessly transmitted semantic signals beyond the electricity used for metabolic operation. C

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DYNAMIC FERROFLUID SCULPTURE: ORGANIC SHAPE-CHANGING ART FORMS

BY SACHIKO KODAMA

From ancient times, standing sculptures in Japan and elsewhere were made of materials such as clay, stone, wood, or metal. Materials were formed, modeled, modified, cut, and reshaped using processes appropriate for them, and the forms and textures of sculptures made from the materials did not change except by abrasion or surface corrosion.

The invention of photography changed this world of unchanging art. Modern materials and electric and machine technology came to be used in artworks and inspired kinetic art such as that by Naum Gabo and László Moholy-Nagy was created. Since then, numerous artists, designers, and architects have created moving, kinetic works.

Since the introduction of the computer (for example, in cybernetic art proposed by Nicolas Shöffer), a number of artworks have been produced by processing external

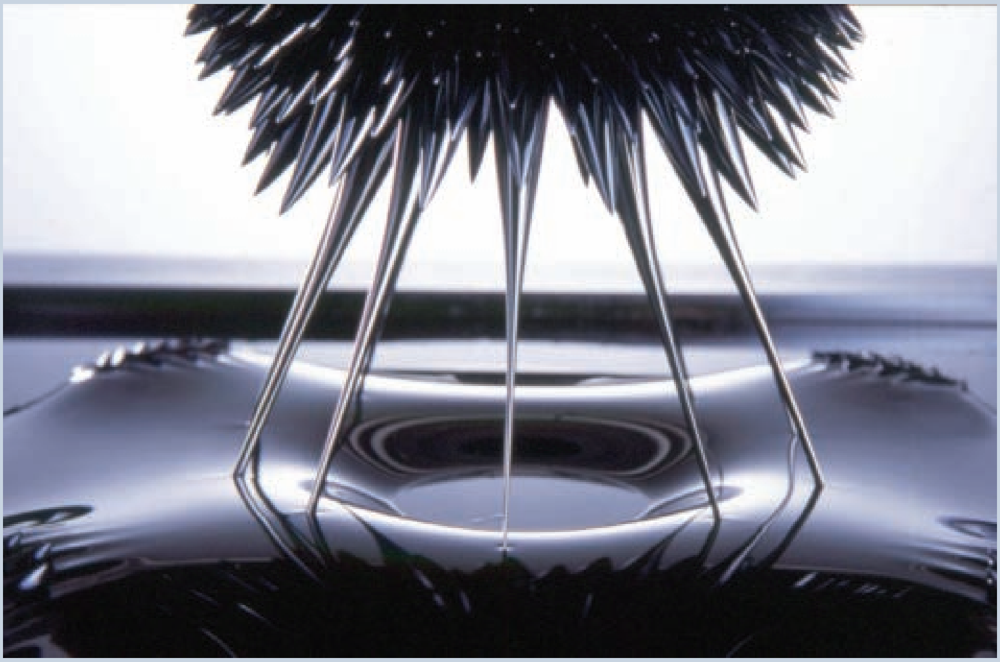

Figure 1. *Protrude, Flow* (2001) by Sachiko Kodama and Minako Takeno. Photograph by Yozo Takada.

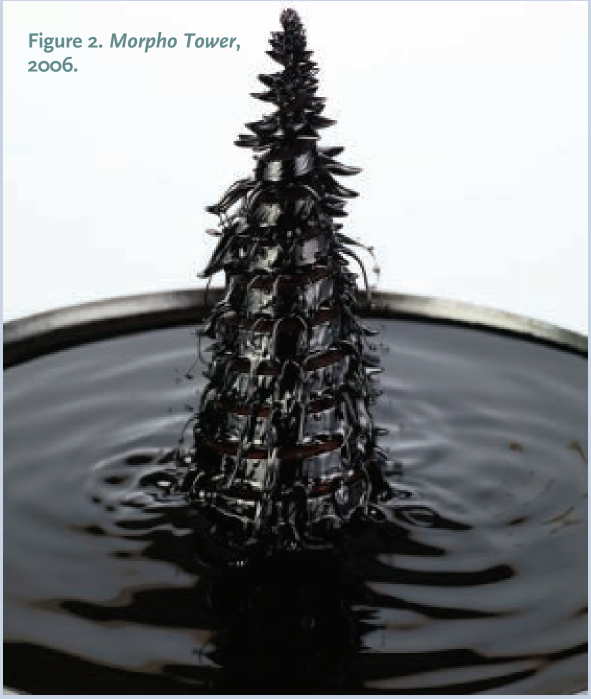

Figure 2. *Morpho Tower*, 2006.

Figure 3. *Morpho Tower/ Two Standing Spirals*, 2007.

information from the environment or living beings through physical devices. However, it can be stated that there has been little work on expression through flexible changes of the surface texture controlled by a computer.

The goal of my project is to create organic shape-changing art forms and figures whose 3D form, surface structure, and color change dynamically and lively as if to reflect echoes of environmental music, light, and human communication. To create such 3D organic forms and surfaces, in 2000 I started using ferrofluid in my interactive art project *Protrude, Flow* (see Figure 1).

Ferrofluids, the shape-changing material used in my works, were invented in the late 1960s in the Apollo Program of the U.S. National Aeronautics and Space Administration (NASA) and are known to be used for forming liquid seals and in electronic devices for computers, audiovisual equipment, and other industrial applications. Recently, they have been employed in medical research.

Ferrofluids, which appear as a black fluid, are prepared by dissolving nanoscale ferromagnetic particles in a solvent such as water or oil and remain strongly magnetic even in a fluid condition. Therefore, they are more flexibly transformable as compared to iron sand. It is well known that ferrofluids form spikes along magnetic field lines when the magnetic surface force exceeds the stabilizing effects of the fluid weight and surface tension [1]. In my work, organic shapes are produced by these spikes under a magnetic field that is controlled by electromagnets. Sensing technology and computers are used to make the fluid change its shape according to environmental information. The transformation of the shape and rhythm of the movement are important aspects of the work.

My first project, *Protrude, Flow*, used six electromagnets. In this work, the electromagnets sometimes prevented people from viewing the moving liquid. To solve this problem and to simplify the work, I discovered a new technique called ferrofluid sculpture. This technique enables artists to create more dynamic sculptures with fluid materials. One electromagnet is used, with an extended iron core that is sculpted into a particular shape. The ferrofluid covers the sculpted surface of the 3D iron shape. The movement of the spikes in the fluid is controlled dynamically on the surface by adjusting the power of the electromagnet.

The *Morpho Tower* series in 2006 was my first realization of a ferrofluid sculpture. Figure 2 shows the spiral tower covered with numerous ferrofluid spikes. A spiral tower is positioned on a plate that holds the ferrofluid. When the magnetic field around the tower is strengthened, spikes of ferrofluid are generated in the bottom plate and move upward, trembling and rotating around the edge of the iron spiral [2].

The movement of the spikes in the fluid is controlled on the surface by adjusting the power of the electromagnet. The shape of the iron body is designed to be helical so the fluid can move to the top of the helical tower when the magnetic field is sufficiently strong. The surface of the tower responds dynamically to its magnetic environment. When there is no magnetic field, the tower appears to have a simple spiral shape. But when the magnetic field around the tower is strengthened, spikes are generated in the ferrofluid; simultaneously, the tower's surface dynamically changes into a variety of textures—a soft fluid, a minute moss, spiky shark's teeth, or a hard iron surface. The ferrofluid reaches all the way to the top of the tower, spreading like a fractal and defying gravity.

The spikes of the ferrofluid are made to rotate around the edge of the spiral cone, where they increase or decrease in size depending on the strength of the magnetic field. Using a computer, the transformation and movement of the shape can be controlled along with its speed and rhythm. The speed of rotation can be controlled without motors or shaft mechanisms, so that it works calmly; simply controlled by gravity and a magnetic field.

The inspiration for my artwork comes from life and nature. The organic forms and the geometry and symmetry observed in plants and animals are important inspirational factors when considering kinetic or shape-changing and potentially interactive art forms. The manner of movement of animals and other natural materials is also important. The breathing rhythms of living things is an excellent metaphor for a texture that dynamically changes over time. One of my eventual goals is to apply these elements in computer display design as well.

The continuously changing weather conditions of the earth are also important motifs. The motifs for the work *Morpho Towers: Two Standing Spirals* [3], which I created in collaboration with Yasushi Miyajima of the Sony Computer Science Laboratory, were ocean, tornadoes, and lightning (see Figure 3). Here, a black tornado elegantly dances in sync with music, reflecting the Japanese concept of comparison. Mimicking natural phenomena ("mitate" in Japanese) is a method that works well when trying to understand how natural shapes occur [4].[1] It permits the comparison of ferrofluid forms to creatures such as sea urchins and jellyfish or to a tornado. Thus, it creates high-tech versions of the Japanese "Hakoniwa," boxes with small models of things and landscapes taken from real-life settings.

When regarded as a ferrofluid display, my sculptures exhibit principles of Organic User Interface design. First, their form follows the flow: the entire shape of the ferrofluid display emerges naturally under the balance of physical forces. In addition, their output may serve as an input. While ferrofluid displays currently primarily serve as an output device, the electromagnet can be used directly as a sensor, allowing the introduction of feedback loops and interactivity in the artworks.

However, what function would be conceivable for such ferrofluid display? Perhaps the focus should be on the entertainment or aesthetic aspects of interactive ferrofluid materials (for example, when applied to carpets or walls), especially if color representation can be realized on their surface. If we consider the sense of touch and the elasticity of the ferrofluid, more practical uses of the ferrofluid display might be found. Now is a time of unprecedented advances in materials science, offering many opportunities to experiment with various materials for constructing organic figures in the creation of interactive art. Such figures are created along a timeline and provide new meanings and new ways of communication. The fusion of information technology and material technology will develop even more in the future, making it possible for them to eventually transform flexibly, like the interactive 3D surfaces shown in the movie *X-men*.

Bits may be transformed into reconfigurable textures and the concept of "bit-texture" may be realized. Even artificial intelligence may be applied to such substances. Is it possible to imagine that we have a third skin on the surface of our own body and on tools, furniture, houses, or other products, a skin that senses information from the environment and its inhabitants, and that responds by morphing according to its required function. If this becomes reality, computers that mimic natural forms may offer a more calm, relaxing, and comfortable user experience. **C**

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[1] With Hiroo Iwata of the University of Tsukuba as the leader, some researchers and artists are proposing "device art," which understands and uses new materials and electronic mechanical devices in a manner similar to tools.

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By Daniel J. Weitzner, Harold Abelson, Tim Berners-Lee, Joan Feigenbaum, James Hendler, and Gerald Jay Sussman

INFORMATION ACCOUNTABILITY

With access control and encryption no longer capable of protecting privacy, laws and systems are needed that hold people accountable for the misuse of personal information, whether public or secret.

Existing legal and technical mechanisms intended to protect our privacy, copyright, and other important values have been overwhelmed by the increasingly open information environment in which we live. These threats follow from the ease of information storage, transportation, aggregation, and analysis. We face the real risk that the technical laws spelled out by Gordon Moore (growth in processing power) and Robert Metcalfe (network effects) will permanently overwhelm our values as enshrined in society's laws.

ILLUSTRATION BY JEAN-FRANÇOIS PODEVIN


WANTED
UNITED KINGDOM
VISA
John H. Dow Credit Limit
based on Annual income
FORNIA
15 OCT 2008
APPLICATION FOR EMPLOYMENT
ALIEN

For too long, our approach to information-protection policy has been to seek ways to prevent information from "escaping" beyond appropriate boundaries, then wring our hands when it inevitably does. This hide-it-or-lose-it perspective dominates technical and public-policy approaches to fundamental social questions of online privacy, copyright, and surveillance. Yet it is increasingly inadequate for a connected world where information is easily copied and aggregated and automated correlations and inferences across multiple databases uncover information even when it is not revealed explicitly. As an alternative, accountability must become a primary means through which society addresses appropriate use. Information accountability means the use of information should be transparent so it is possible to determine whether a particular use is appropriate under a given set of rules and that the system enables individuals and institutions to be held accountable for misuse.

Transparency and accountability make bad acts visible to all concerned. However, visibility alone does not guarantee compliance. Then again, the vast majority of legal and social rules that form the fabric of our societies are not enforced perfectly or automatically, yet somehow most of us still manage to follow most of them most of the time. We do so because social systems built up over thousands of years encourage us, often making compliance easier than violation. For those rare cases where rules are broken, we are all aware that we may be held accountable through a process that looks back through the records of our actions and assesses them against the rules.

Personal privacy, copyright protection, and government surveillance are among the more intractable policy challenges in our information society. In each of these policy areas, excessive reliance on secrecy and up-front control over information has yielded policies that fail to meet social needs, as well as technologies that stifle information flow without actually resolving the problems for which they were designed.

Information privacy rights aim to safeguard individual autonomy against the power that institutions or individuals gain over others through the use of personal information.[1] Sensitive, and possibly inaccurate, information may be used against people in financial, political, employment, and health-care settings. In democratic societies, citizens' behavior is unduly restrained if they fear they are being watched at every turn. They may deliberately avoid reading controversial material or feel inhibited from associating with certain communities and ideas for fear of adverse consequences.

Protecting privacy is more challenging than ever due to the proliferation of personal information on the Web and the increasing analytical power available to large institutions (and to everyone else) through Web search engines and other facilities.[2] Access control and collection limits over a single instance of personal data are insufficient to guarantee the protection of privacy when either the same information is publicly available elsewhere on the Web or it is possible to infer private details to a high degree of accuracy from other information that itself is public [8, 10]. Worse, many privacy protections (such as lengthy online privacy-policy statements in health care and financial services) are mere fig leaves over the increasing exposure of our social and commercial interactions. In the case of publicly available personal information, people often intentionally make the data available, not always by accident [9]. They may not intend for it to be used for every conceivable purpose but are willing for it to be public nonetheless.

Even technological tools that help individuals make informed choices about data-collection practices are no longer sufficient to protect privacy in the age of the Web. As a case in point, the growth of e-commerce over the second half of the 1990s sparked concern among Web users worldwide about their personal privacy and led businesses to emphasize Website privacy policies and infrastructure (such as the World Wide Web Consortium's Platform for Privacy Preferences, or P3P, www.w3.org/P3P/). A fully implemented P3P environment gives Web users the ability to make privacy choices about every single request by business organizations and government agencies to collect information about them. However, the number, frequency, and specificity of these choices would be overwhelming, especially if they were to cover all possible future uses by the data collector and by third parties. Individuals should not have to agree in advance to complex policies with unpredictable outcomes. Moreover, they should be confident that there will be redress if they are harmed by the improper use of the information they provide. Otherwise, individuals cannot be expected to be motivated to attend to privacy choices.

Consider the complexities of protecting privacy in this scenario: Alice is the mother of a three-year-old child with a severe chronic illness. She learns all she can about it, buying books online, searching the Web,

[1] There are numerous definitions of privacy. Our chief interest here is understanding privacy rights as they relate to the collection and use of personal information, as opposed to other privacy protections that seek to preserve control over, say, one's physical integrity.

[2] See the authors' technical report; dspace.mit.edu/bitstream/1721.1/37600/2MIT-CSAIL-TR-2007-034.pdf.

In democratic societies, citizens' behavior is unduly restrained if *they fear being watched at every turn.*

and participating in online parent-support social networks and chat rooms. She then applies for a job and is rejected, suspecting it's because a background check identified her Web activities and flagged her as high risk for expensive family health costs.

Such tales are offered to support the argument for Web privacy. Did, say, the online bookstores assert that the titles of Alice's purchases would be kept confidential? Did AOL promise never to release information about her online searches? Did the chat service guard against lurkers in the chat room, recording the names of every participant? A policy regime based on information hiding would focus on these potential acts of data release, perhaps even taking the position that it is Alice's own personal responsibility to inform herself about the privacy policies of Web sites before using their services. This focus is misplaced. The actual harm was caused not by the disclosure of information by the bookseller, AOL, or chat service, but by the decision to deny Alice the job, that is, by the inappropriate, discriminatory, and possibly illegal use of the information. It is quite conceivable that Alice wants to be publicly identified as someone with an interest in her child's illness. Forcing her to hide it to protect herself against improper information use significantly limits her ability to exercise her right to freedom of association. Rather, Alice (and everyone else) should be able to live in an online environment that provides transparent information use and accountability to rules that limit the harmful use of personal information.

COPYRIGHT

Looking into copyright and government surveillance reveals deficiencies in the reliance on information hiding as a policy tool. In the copyright context, information hiding commonly takes the form of digital rights management (DRM). As with personal privacy, locking up information is extremely difficult, and efforts at up-front control over the information flow results in user frustration and substantially imperfect security. This is a lesson that even the most ambitious online businesses have learned. For example, in early 2007, Apple CEO Steve Jobs wrote that DRM has not worked nor is it ever likely to work [5]. Soon thereafter, Apple changed the way it sells music online by offering a higher-priced version of its download service unencumbered by DRM. Apple now implements a basic form of information accountability. The newly unlocked tracks include the purchaser's name and other personally identifying information. That way, if he or she shares the purchased music with, say, a hundred million closest friends through the Internet, the purchaser could be held accountable.

The Creative Commons, another approach to online copyright protection, likewise does not rely on up-front enforcement of licenses. Rather, its architecture, based on rights expression, not access restriction, recognizes the value of having information flow freely around the Internet but still seeks to impose certain restrictions on how the information is used.

GOVERNMENT DATA MINING

Recent government use of advanced data mining techniques is another example of the deficiency of access-control and collection-limitation approaches to privacy compliance on the Web. Laws that limit access to information do not protect privacy here because so much of the data is publicly available. To date, neither law nor technology has developed a way to address this privacy loophole [2].

Airline passenger screening by law enforcement and national security agencies illustrates the growing complexity of information handling and transfer. Society may be prepared to accept (and even expect) national security agencies to use aggressive data mining techniques over a range of information in order to identify potential terrorism risks. But citizens find it unacceptable to use the same information with the same powerful analytic tools to investigate domestic criminal activity. Therefore, we need rules in the U.S. (and globally) that address the permissible use of certain classes of information, in addition to simple access and collection limitations.

LEGAL FRAMEWORK

The information-accountability framework more closely mirrors the relationship between the law and human behavior than do the various efforts to

Information accountability means that *information usage should be transparent* so it is possible to determine whether a use is appropriate under a given set of rules.

enforce policy compliance through access control over information. As an early illustration of information accountability at work today, consider credit bureaus and their vast collections of personal information. When these databases came on the scene in the consumer financial markets of the 1960s, policymakers recognized the public imperative to protect individual privacy and assure data accuracy, all while maintaining enough flexibility to allow analysis of consumer credit data based on the maximum amount of useful information possible. Under the Fair Credit Reporting Act (enacted 1970) [3], privacy is protected not by limiting the collection of data, but by placing strict rules on how the data may be used. Analysis for the purpose of developing a credit score is essentially unconstrained, but the resulting information can be used only for credit or employment purposes. It cannot be used for marketing and other profiling. Strict penalties are imposed by the FCRA for the breach of these use limitations. Data quality is protected by giving all consumers the right to see the data held about them (transparency). If a user of the data makes a decision adverse to the consumer (such as denial of a loan or rejection of an employment application) the decision must be justified with reference to the specific data in the credit report on which the decision was based (accountability). If the consumer discovers that the data is inaccurate, he or she may demand that it be corrected. Stiff financial penalties are imposed by the FCRA against the credit bureau if it fails to make the appropriate corrections.

The typical consumer appreciates the paradox associated with protecting privacy and other information policy values through increased transparency. As the FCRA illustrates, we achieve greater information accountability only by making better use of the information that is collected and by retaining the data that is necessary to hold data users responsible for policy compliance. The success of this accountability regime for the past 40 years over a very large set of data—credit reports on nearly every adult in the U.S.—makes it a worthy model for considering policy compliance in other large systems.

TECHNICAL ARCHITECTURES

What technical architecture should be required to support information accountability? Our goal in promoting accountability systems is to build into our information infrastructures the technology necessary to make acts of information usage more transparent in order to hold the individuals and institutions who misuse it accountable for their acts. Systems supporting information accountability require three basic architectural features:

Policy-aware transaction logs. In a decentralized system each endpoint must assume the responsibility of recording information-use events that may be relevant to the assessment of accountability to some set of policies.

Policy-language framework. Assessing policy compliance over a set of transactions logged at a heterogeneous set of endpoints by diverse human actors requires a common framework for describing policy rules. Drawing on semantic Web techniques, larger and larger overlapping communities on the Web can develop shared policy vocabularies in a bottom-up fashion. A lack of perfect global interoperability of these policies is not a fatal flaw. Just as human societies learn to cope with overlapping and sometimes contradictory rules, so too are policy-aware systems likely to develop at least partial interoperability [1].

Policy-reasoning tools. Accountable systems must be able to assist users in answering such questions as: Is this data allowed to be used for a given purpose? and Can a given string of inferences be used in a given context, in light of the provenance of the data and the applicable rules? One possible approach to designing accountable systems is to place a series of accountable appliances throughout the system that communicate through Web-based protocols [7]. Accountability appliances would serve as proxies to data sources, mediating access to the data, and maintain provenance information and logs of data transfers. They could also present accountability reasoning in human-readable ways and allow annotation, editing, and publishing of the data and reasoning being presented [6]. This aspect of the accountability and transparency perspective is closely related to the issue of maintaining provenance for scientific data [4, 11].

CONCLUSION

Alan Westin published his landmark study *Privacy and Freedom* in 1967 [12]. Still in the age of mainframe computers, it set the stage for thinking about privacy over the next three decades. Westin presented what has become a classic definition of privacy, emphasizing the individual's right to control how personal information "is communicated to others." An information-accountability perspective on privacy would reframe this definition, shifting toward the use of any information. Following Westin, we would say that privacy is the claim of individuals, groups, and institutions to determine for themselves when, how, and to what extent information about them is used lawfully and appropriately by others.

Westin's work is essential today for identifying the role of privacy in a free society. However, advances in communications and information technology and the ease of data searching and aggregation have rendered his definition incomplete as a framework for information policy and information architectures that are intended to be policy aware.

Will the new tools and laws we've described here put an end to all privacy invasion, unfair misuse of personal information, copyright infringement, and identity theft? Of course not. Perfect compliance is not the proper standard by which to judge laws or systems that help enforce them. Rather we should ask how to build systems that encourage compliance and maximize the possibility of accountability for violations. We should see clearly that our information-policy goals cannot be achieved by restricting the flow of information alone. While the accountability approach is a departure from contemporary computer and network policy techniques, it is far more consistent with the way legal rules traditionally work in democratic societies.

Contemporary information systems depart from the norm of social systems in the way they seek to enforce rules up front by precluding the possibility of violation, generally through the application of strong cryptographic techniques. In contrast, we follow rules because we are aware of what they are and because we know there will be consequences, after the fact, if we violate them. Technology will better support freedom by relying on these social compacts than by seeking to supplant them. C

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By Charalambos L. Iacovou and Robbie Nakatsu

A RISK PROFILE OF OFFSHORE-OUTSOURCED DEVELOPMENT PROJECTS

Even the best project management skills will not guarantee success in the complex world of offshore outsourcing.

As part of a development initiative, Life Time Fitness, a U.S.-based health club chain, outsourced the implementation of a software application to an Indian information technology (IT) services vendor. The application was a decision support system to evaluate prospective gym locations. The company's decision to pursue offshore outsourcing for its development was motivated by the opportunity to tap into low-cost, well-trained IT talent.

Life Time Fitness pursued this initiative with fervor. The vendor was evaluated carefully and the project was planned in detail, but despite these efforts the development initiative ran into problems. The quality of the early deliverables was poor due to inadequate knowledge transfer between the U.S. resources and the Indian professionals. Moreover, miscommunication between the two groups compounded the project troubles, resulting in delays and overspending. The woes continued to escalate until Life Time Fitness terminated the contract and brought the system back in-house for its own programmers to rework [10].

While this story is troubling, it is not atypical in the offshore outsourcing of software development [1]. Unless an organization is well-equipped to deal with the challenges of offshore outsourcing, its projects are bound to go awry. Indeed, a survey reveals that eight out every 10 businesses that have entrusted application development to an offshore vendor have experienced major problems due to inadequate preparation and ineffectual management [3]. Still, given the significant economic benefits that companies can potentially reap, it is not at all surprising that offshore outsourcing is growing in size and importance. According to Forrester Research, 65% of American and European enterprises (with 1,000 or more employees) currently use offshore providers for application development; another 13% plan to begin doing so in the next year. Two years ago, only 45% of such organizations utilized offshore vendors to develop applications [7]. Given this trend, there is a clear need to better understand how to manage offshore projects more effectively.

Rank	Risk Factor	Rating*
1	Lack of top management commitment	9.2
2	Original set of requirements is miscommunicated	8.1
3	Language barriers in project communications	7.7
4	Inadequate user involvement	7.7
5	Lack of offshore project management know-how by client	7.4
6	Failure to manage end user expectations	7.3
7	Poor change controls	7.3
8	Lack of business know-how by offshore team	7.3
9	Lack of required technical know-how by offshore team	7.2
10	Failure to consider all costs	7.1
11	Telecommunications and infrastructure issues	6.8
12	Vendor viability	6.0
13	Difficulties in ongoing support and maintenance	6.0
14	Low visibility of project process	5.8
15	Cross-cultural differences	5.8
16	High turnover of vendor employees	5.8
17	Constraints due to time-zone differences	5.8
18	Lack of continuous, face-to-face interactions across team members	5.7
19	Threats to the security of information resources	5.3
20	Negative impact on employee morale	5.2
21	Unfamiliarity with international and foreign contract law	4.8
22	Differences in development methodology/processes	4.8
23	Political instability in offshore destinations	4.4
24	Negative impact on image of client organization	3.1
25	Currency fluctuations	2.8

* The following rating scale was used to assign importance by the experts: 10=very important; 7=important; 4=slightly important; and 1=unimportant.

Table 1. Rankings of risk factors.

While problems can develop in both in-house and domestically outsourced projects, offshore-outsourced projects are especially prone to failure. This is a significant concern for IT managers who are constantly seeking ways to increase the success record of their development efforts. To assist such managers, we conducted a study of the risk factors of offshore-outsourced development. These factors refer to conditions that can present a serious threat to the successful completion of a project if left unmanaged [9]. Given the evidence linking project risk factors to outcomes [11], we believe that a clear identification of the risk profile of such projects will help managers steer their projects to successful completion [1].

While prior studies have examined the risks of software development [9], such investigations did not specifically consider the offshore outsourcing context. Rather, these studies focused on in-house and domestically outsourced initiatives. Due to the increased complexity and the distinctive managerial challenges that exist in offshore outsourcing environments [1, 2, 4, 6], we expected that the risk profile of offshore projects would be somewhat different from that of non-offshore ones. Thus, our goal was to produce a set of project risks that specifically applies to offshore outsourcing by building upon the earlier research.

To identify the risk factors, we sought the input of the individuals that companies recruit to manage offshore projects: experienced senior project managers and directors. To identify such experts, we contacted certified project management professionals (PMP), who are senior IT executives and members of the Project Management Institute (PMI). We asked these managers to complete a form summarizing their experience. After screening the qualifications of 57 such individuals, we selected 15 of them to partici-

As a recent ACM report suggests, *outsourcing "magnifies existing risks and creates new threats."* Thus, offshoring clients will be well advised to spend the resources needed to assess the increased exposure to risk and its sources, and to identify ways to mitigate it.

pate in our study. Each of the selected executives had managed multiple offshore projects in the past; in total, the panelists had managed 135 such projects. On average, each panelist had over 17 years of IT-related experience and over 15 years of project management experience, and had managed 51 projects, nine of which were offshore development ones. This level of expertise suggests that the selected panel was well-qualified for the task.

To solicit the input of these experts, we utilized the Delphi survey method. A brief description of how their input was collected and analyzed is provided in the sidebar "How the Study was Conducted." Table 1 summarizes the risk factors as identified and rated by the experts.

The results of our study represent a set of conventional risk factors that have been previously identified by well-cited research [5, 9, 11], as well as threats that are more distinctive to offshoring. On average, the risks that relate to long-established factors (risks 1, 2, 4, 6–10, 12, 13 and 16) have been ranked higher than the factors that are relatively unique to offshoring (risks 3, 5, 11, 19–21 and 23–25). This suggests that, for the most part, offshore initiatives experience the same fundamental issues that affect non-offshore ones. However, as the panelists' ratings and insights reveal, these traditional risks are likely to pose more severe threats in the offshoring context due to the complexity and the specific challenges that are inherent in multinational, distance-based working teams. While the novelty of some of the risks could be questioned, their importance to effective project management should not be discounted. As a recent ACM report suggests, outsourcing "magnifies existing risks and creates new threats" [2]. Thus, offshoring clients will be well advised to spend the resources needed to assess the increased exposure to risk and its sources, and to identify ways to mitigate it [2].

Rank	Risk Factor
1	**Lack of top management commitment** Without meaningful top management support and commitment, projects face challenges that can lead to political battles, delays and even rejection. Top management support is essential in securing the needed resources and cooperation across organizational groups, and for enhancing the legitimacy of the project.
2	**Original set of requirements is miscommunicated** Ensuring that the developers and the end users have a consistent understanding of the requirements can be a challenge in offshore development because of the reduced face-to-face, informal communications between these two groups. No matter how specific the requirements report is, there is often a window for assumptions to be made. This is especially true in development situations that are based on long-distance collaborations.
3	**Language barriers in project communications** Language differences make project communications difficult and can lead to delays and conflicts. Even when all parties speak English, there may be misunderstandings because much of our language is based on cultural assumptions. Also, slang terminology and accents can create problems and may slow down communications. Conducting reviews over the phone can be problematic (due to the linguistic differences among team members). Frequent give-and-take may be needed to reach understanding. Overall, it takes more time and effort to communicate effectively in offshore projects.
4	**Inadequate user involvement** Effective user involvement is a critical success factor in any project. However, many offshore projects are stewarded by IS groups without significant participation by users. This can lead to conflicts, delays and other problems. Participation helps educate users about the risks and challenges of software development.
5	**Lack of offshore project management know-how by client** Offshoring is new to many companies. Many of them don't have the in-house expertise that is needed to adequately monitor offshore work and to incorporate effectively the new technology into their existing portfolios. In addition to traditional project management factors, offshore development requires effective management of several specialized issues. For example, the need to delineate responsibilities across the duplicate project management structure is not always fully understood. The lack of project management know-how can lead to cost and time overruns.
6	**Failure to manage end user expectations** Expectations must be managed to ensure that the project deliverables will be consistent with the perceptions of the users. This is a difficult task in all projects, but it is especially challenging in offshore situations because the users are not in direct contact with the developers. If expectations are not managed properly, the software may not be accepted by the end users.
7	**Poor change controls** Changes to the initial set of requirements can cause delays, overruns, and other problems if they are not managed properly. Even when changes are documented and justified properly, there may be delays due to the exchange of questions and answers that must take place before the change is understood. Also, remote offshore resources may not obtain the sense of urgency for the changes without extended effort. If scope modifications are not managed well, they can result in overruns and hostile situations, especially in fixed price or penalty contracts.
8	**Lack of business know-how by offshore team** Frequently, overseas resources do not have an intimate understanding of the client's business context and don't get sufficient training on it. Lack of business know-how and lack of access to key business contacts (to get things done) can cause delays. Choosing a vendor (with good technical skills) without regard to domain expertise can lead to trouble. Domain understanding is critical in offshore projects as normal workflow in one country may be inappropriate (even illegal) in another.
9	**Lack of required technical know-how by offshore team** Ensuring that the development team consists of quality resources can be a challenge. Sometimes the skills and knowledge of offshore resources are misrepresented by vendor management. In other situations, the level of technical sophistication in a country is lower than that of the USA, limiting the pool of expert resources. Moreover, good vendor resources may be overcommitted. Even though some vendors are "process capability" certified, their depth of expertise could be limited.
10	**Failure to consider all costs** Typically, firms do not consider all the costs associated with offshore outsourcing. Many hidden costs can exist in such arrangements. For example, travel expenses for moving and hosting development resources on-site in the U.S are often underestimated. Costs associated with delays and rework due to miscommunication also tend to be ignored. Finally, costs associated with the "duplicate" project team structure (for having a manager onshore and another offshore) are often overlooked.

Table 2. Top risk factors.

IMPORTANT RISK FACTORS IN OFFSHORE PROJECTS

While we recognize the significance of all identified risks, we concentrate our discussion on the top 10 factors as described and ranked by the experts in our panel (see Table 2). These 10 were rated as "very important" or "important" by the expert panel in its final evaluation. Given the significant level of consensus among the experts, we believe that this list represents the most notable set of risks salient to offshore projects.

As the findings indicate, the risks focus on three major areas of concern: the communication between the client and the vendor, the client's internal man-

"You will get exactly what you asked for, so you better make sure you are asking for *exactly the right thing*."

agement of the project, and the vendor's capabilities. The identified risk factors for each of these areas are discussed next. Our discussion focuses on insights by the panelists that highlight the factors' significance to offshoring.

Client-vendor communications. The panel was of the opinion that most offshore projects are susceptible to miscommunications that can complicate the transmission of the original set of requirements and subsequent information exchanges and change requests. These concerns were expressed in three related risk factors.

Miscommunication of the original set of requirements (factor #2) was identified as a major risk because, as a panelist pointed out:

"Language, environmental, and other factors play a huge part in how people read and understand things. No matter how specific the requirements, there is often a window for assumptions to be made. This is especially dangerous when you are talking about long-distance collaborations."

Nonetheless, according to the panel, getting the requirements straight is essential because "with less opportunity for interaction with development resources offshore, a much higher premium is put on the quality of the requirements." Another expert identified a related danger associated with the highly structured processes that are instituted by many vendors: "you will get exactly what you asked for, so you better make sure you are asking for exactly the right thing."

Language barriers in project communications (#3) also received extensive attention by the experts. This is not surprising given the language and cultural differences that exist in multinational teams and the difficulties of remote collaboration [6]. As an expert pointed out, such challenges exist even when all project members speak the same language: "even when both parties speak English, there is a major chance for misunderstanding because much of our language is based on cultural assumptions." Due to these differences, even simple information exchanges during the project execution can become lengthy and complex as "frequent give and take" is needed before the parties understand each other.

The final communications-related risk was poor change controls (#7). Ineffective controls can lead to scope creep, a recognized threat that affects all types of projects. However, the experts suggested that this risk takes on a more prominent role in offshoring because of the communications issues identified above. Moreover, physical distance (and the lack of informal interactions between developers and users) is likely to affect the handling of change requests as "offshore destinations, being remote and distant, do not have the same sense of urgency as the client organization about the need for changes."

Client's internal management issues. Three traditional client-related risk factors (lack of top management commitment, inadequate user involvement, and difficulty in managing end-user expectations) were deemed important by the experts. In addition, they identified two other risks rooted in the newness of the offshoring phenomenon: the lack of relevant project-management know-how, and the inability to fully consider all relevant costs.

Consistent with prior research [9], lack of top management commitment was ranked as the #1 risk. Several panelists noted that for all types of IT projects, offshore-outsourced or not, senior management support is essential. As a panelist wrote, "this issue is not unique to offshore projects, but is rather a generic project issue faced by all projects regardless of the location of the different management and staff."

Inadequate user involvement (#4) was also identified as a critical threat. Several panelists noted that many offshore projects are frequently directed by IS groups with inadequate user participation. Given the significance of such involvement and its positive impact on system acceptance and usage [9], it is imperative to meaningfully engage users in the project. As a panelist pointed out, involvement is also important because of its political value.

"Most offshore projects are stewarded by IT groups on behalf of the users. If you think your IS department is far removed from the development work, you will probably find that your user (who is paying for the software) is even farther removed. If there is a vendor problem, then it is much better that the user sees the vendor messing up, so that the IT group does not end up with the entire blame for the failure."

Lack of offshore project management know-how by the client (#5) was identified as a significant threat because, as a panelist observed, "offshoring is new to many companies, and their lack of experience in dealing with outsourced vendors introduces risks in most areas of the project operation." Another expert pointed out that such a lack of experience makes clients vulnerable because "the vendor tends to 'run the show' and the project becomes a case of the 'tail wagging the dog'." Many experts indicated that specialized project management know-how is needed to deal with the unique challenges of offshore projects. One such challenge relates to the duplicate management structure (the offshore team and the client organization) that is typically found in offshore projects: "splitting management causes confusion at the project level through difficulties in scheduling resources and tasks, determining overall project direction, and adds another full communications layer." Overall, the panelists warned that clients who are inexperienced or ill-equipped to manage remote collaborative environments are likely to experience major project problems.

Managing end-user expectations (#6) was identified as a major project risk as well. As a panelist indicated this is "always in the top risks for any project. It does not matter if it is offshore. Managing end-user expectations is one of the largest and most difficult jobs a project manager is tasked with." Given the distance and communication issues that exist in offshore environments, understanding, influencing, and meeting such expectations can be particularly difficult.

Failure to consider all costs (#10) rounds out our discussion on client-focused risk factors. Participants stated that in offshoring, several communication-related, overhead, and intangible costs are likely to get overlooked because of the newness of the offshore phenomenon. One panelist relayed the following example: "the offshore resources had to come to the states to be trained for several weeks. The cost of airfare, lodging, and food as well as time lost getting the individuals to our local sites, were higher than expected and continued longer than expected." Another spoke about the frequently unanticipated cost of longer working hours due to time differences: "The client project manager should be willing to work longer hours—in addition to doing his or her normal work during the day time at the office, he or she is also expected to handle calls and questions from the outsourced company at odd hours."

HOW THE STUDY WAS CONDUCTED

This study utilized a three-round Delphi survey to solicit and analyze the input of the expert panelists. The Delphi method allowed us to elicit their input through an iterative, controlled feedback process. To execute the study, we followed the methodology prescribed by Schmidt [8] that aims to achieve consensus among the experts and provides a statistical analysis for assessing the level of such consensus.

In the first round, we asked the experts to identify the most important risk factors that could influence the outcome of an offshore-outsourced application development project. The experts were asked to describe at least six such risk factors. The goal of this round was to discover the possible set of all relevant risk factors. To allow the experts to consider prior work on risk factors (which refer to non-offshore development situations), we provided them with a list of the top 18 risk factors identified by a well-cited study [9]. After reviewing the experts' input, we consolidated it into 25 unique risk factors. This consolidation process was conducted independently by the two researchers. Any discrepancies between them were resolved through discussion and by consensus. The generated list was validated by the experts in round two.

In the second round of the study, we presented the 25 identified risk factors and asked the experts to confirm that they were consistent with their initial input. We also asked them to rate each risk factor according to its importance to the successful completion of the project. After receiving their input, we calculated the average importance rating for each risk factor.

In the third and final round, for each risk factor, we provided the experts with their own rating from round two along with the average rating of the panel. We asked them to consider the input of their peers and revise their importance ratings if necessary. We also asked them to rate the effectiveness of the Delphi process as a way for them to express their opinions.

An analysis of the ratings indicated that the level of consensus in the opinions of the experts increased significantly between rounds two and three. The average standard deviation between the two rounds decreased from 2.1 to 1.5. More importantly, statistical analysis (using Kendall's Coefficient of Concordance) suggested that the level of consensus at the conclusion of the study was moderate-to-strong ($W=0.53$) and was statistically significant ($p<0.001$). The experts' rating scores overwhelmingly indicated that the Delphi process was an effective way for them to provide their input.

Vendor capabilities. The last two factors—a lack of business know-how (#8) and a lack of technical know-how (#9) by the offshore team—relate to the qualifications of the chosen vendor. With respect to business know-how, the panel observed that an uninformed vendor is more likely to miss things or develop deliverables that need rework. As a panelist noted, "technical decisions are made daily by the offshore teams we manage. Their incomplete understanding of business

Unless organizations recognize the unique challenges associated with remote management in offshoring and provide appropriate training to their project managers, *their initiatives are likely to face increased levels of failure risk.*

needs almost always results in a high number of flawed technical decisions that must be revisited and corrected at later stages." Thus, it may be useful to work with a vendor familiar with the native business context of the client. This may be especially valuable when the project requirements are not well structured and design decisions will need to be made during the project execution.

With respect to technical know-how, most panelists acknowledged that offshore vendors are more often than not adept in software development work. But the experts also indicated that without easy access to the assigned resources and a clear visibility of their working patterns, assessing vendor capabilities can be tricky. For example, one panelist warned that "any large offshore outsourcer will likely have a claim of a high CMMI [Capability Maturity Model Integration] level. However, this is not fully indicative of the process maturity of the actual team that will be working on the project." Another cautioned that "the available skills and knowledge are sometimes misrepresented by offshore management or are not available when needed on the project schedule." While a precontract evaluation can help, the experts commented that assessing a vendor's technical capabilities can be difficult due to the "black box" nature of the offshore team.

CONCLUSION

Offshore projects are by their very nature risky undertakings. As the study findings reveal, such projects face a combination of traditional project risks as well as a set of threats that are fairly unique to the offshore environment. Unquestionably, fundamental project management skills are essential in guiding such projects. However, such skills alone are likely to be insufficient in directing offshore initiatives effectively. Unless organizations recognize the unique challenges associated with remote management in offshoring and provide appropriate training to their project managers, their initiatives are likely to face increased levels of failure risk.

Because our findings represent the input of a panel of experts with extensive offshore outsourcing experience, we believe these findings are broadly applicable across diverse project types and business contexts. Nevertheless, we recognize that individuals in charge of offshore projects may sometimes face unique organizational settings (such as a heightened sensitivity to PR issues surrounding offshoring, or a lack of needed resources). Such distinctive circumstances will require the development of a customized risk profile for the project, that may differ from the one presented here. We hope that the set of the risk factors and the insights that were generated by the expert panel will provide a useful starting point for such managers. C

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UBIQUITOUS ACCESS: ON THE FRONT LINES OF PATIENT CARE AND SAFETY

UA initiatives help allay potentially fatal errors, improve patient safety, and boost overall quality of care.

The U.S. Institute of Medicine has reported that nearly 98,000 people die each year due to medical errors, such as incorrect medication dosages due to poor legibility in manual records, or delays in consolidating needed information to discern the proper intervention [6]. Many of these grievous mistakes could almost certainly be avoided with faster, more comprehensive, more accessible patient documentation at the point of care [6]. Fortunately, institutions are beginning to recognize the fact that employing point-of-care information technology (IT) can increase patient safety and reduce medical errors [12]. In light of these concerns and a severe nurse shortage (an estimated 400,000 shortage by 2020 exacerbated by overwhelming administrative tasks, like laborious manual documentation requirements), an increasing number of hospitals are implementing ubiquitous access [7]. The aim is to reduce caregiver error, streamline convoluted processes, and ease nurse administrative workloads by providing readily available access to enter and retreive current complete patient information when and where most needed—at the point of care [5, 7].

In our research, we examined the use of ubiquitous access (UA) to medical and patient information via mobile information communication technologies (MICTs) by hospital nurses, because they are at the front lines of care and safety. Overtaxed nurses assume even more responsibilities, and the impending nurse crisis may endanger patients if nurses are belabored with antiquated methods of information acquisition (such as hastily handwriting notes or entering information into a computer away from the point of care—both error-prone and labor-intensive procedures) [7].

Sixty-two percent of respondents from a survey of 100 U.S. health care IT decision makers cited wireless enablement of the clinical documentation process as a top priority between 2004 and 2006 [3]. However, IT

BY CHON ABRAHAM, RICHARD THOMAS WATSON, AND MARIE-CLAUDE BOUDREAU

budgets in the U.S. health care industry have historically been low but are expected to grow to $39.5 billion through 2008 [10]. Our findings suggest that knowing more about the actual benefits derived from UA by studying use at the work process level may spark increased acceptance. At the same time, UA is not without meaningful adoption and usage issues [8]. This is especially true in health care contexts [12].

We selected medical units employing UA for various tasks at the point of care in three hospitals. Technologies supporting UA were lightweight computers mounted on carts to allow mobility (see the accompanying figure). Table 1 provides hospital characteristics and summarizes our data collection. The data was collected post-implementation, when UA had been operational in each unit for at least three months. We interviewed nurses, managers, and information systems personnel at each hospital. We summarize the findings before discussing our recommendations:

Mobile UA cart.

UA provides nurses with essential information at the point of care. UA reduces nurses' charting time and anxiety, enabling them to stay longer with patients and chart multiple patients simultaneously. UA helps nurses create comprehensive, readily accessible records for any authorized personnel to review in real time. This relieves them from having to communicate patient information orally. Even though UA may promote reduced socialization among nurses, which people external to the context may perceive as an impediment to acceptance, it is balanced by the efficiency improvements in the work process (such as decreased time for task completion and less congestion at central computing points). Vital information can be difficult to transmit even among willing parties. UA increases in value when systems facilitate detailed records-keeping, reduce charting time, and enhance readability. Consider the following quote from a triage nurse:

"The main benefit...is that you can look up information about their previous care—how many times they have been here for the same complaint—as you triage. Some don't want to tell you that they are HIV patients, so when you review their history you can see that... [UA] makes the triage process quicker. [Before UA] by the end of the day, your hand's cramping. You forget some things or can't read what you wrote, which can cause you to make mistakes."

UA automates the documentation and knowledge inquiry portion of the work process. It also informs in that it provides nurses and intended medical personnel with extensive mutual awareness of the situation in which they are involved [4]. UA supports more timely and efficient information analysis in negotiations between medical personnel concerning aspects of the care-delivery process. For example, in medication administration, if a nurse believes the prescription to be erroneous or not effective, the nurse can enter an inquiry in the system to more efficiently alert the physician and pharmacists via an integrated messaging system. This process is less convoluted and time-consuming than the use of manual records.

Benefits and limitations influencing acceptance of UA. Primary benefits that promote acceptance are:

- Reduced time required to validate questionable drug prescriptions and medical interventions, which can delay patient care;
- Greater ability for nurses (and subsequently the hospital) to defend against accusations of, and liability for, negligent care;
- Easier and timelier quality assurance for processes and verification associated with patient care; and
- Greater ability for registration personnel and nurses to maintain patient confidentiality by silently reviewing existing information. Also, UA can offer resources of needed information for situated action. For example, nurses can better negotiate with patients to comply with medication regimens by using the system as a medium at the point of care. As a nursing informatics director reports:

"You can use the computer system to be a part of the [patient and caregiver] relationship. You develop interfaces with graphics that the doctor [or nurse] can use to better explain conditions to the patient. For example, you can create a graph of depicting how a patient's blood sugar is not under control based on historical data. You can show them and ask: 'What are they doing? Are they not taking the medication?' Or you can say, 'You are doing very well on this weight reduction plan for the past three years,' and you can show that to them in terms and schematics that they can understand... You can also reassure the patient that he or she is being given the right med, which fosters trust... The patient becomes engaged that way in [his or her] own health care information... The patient becomes a partnet in managing their own health care and taking some responsibility to make sure the data they see in the record is correctly associated with them."

Hospital	Unit	IS Description	Data
Not-for-profit, 528 beds in north Florida	Emergency department	Electronic documenting of patient triage and registration information	Interviews: 15 Observations: 12 Archival material : 20-page project proposal description
Not-for-profit, 124 beds in middle Georgia	Ambulatory care unit	Electronic charting of pre-surgery assessments	Interviews: 15 Observations: 22 Archival material: 115 pages of system documents
	Post-anesthesia care unit	Electronic charting of post-surgery assessment	Interviews: 10 Observations: 13 Archival material: 14 pages of system documents
Federally funded, 478 beds in middle Florida	In-hospital stay	Electronic documenting of medication administration	Interviews: 10 Observations: 10 Archival material: 320 pages of system documents

Table 1. Hospital characteristics.

Limitations that hinder acceptance are:

- The inability to generate desired benefits when technologies, such as document and label printing and copying are not bundled with UA on a mobile workstation;
- Cumbersome IS designs that divert nurses' attentions away from patients;
- Nurses' lack of typing skills, lack of professional exposure and training to IS/IT, or general technology aversion; and
- The short battery life of power packs for mobile workstations.

RECOMMENDATIONS

How can hospitals take full advantage of UA specifically to address the documentation and information acquisition components of nursing workflow? We propose seven action steps for attaining the full benefits of UA:

1. Nursing education programs should integrate electronic patient-care-documentation-skills development into nursing curricula.

While some nursing programs include basic information systems/personal computing classes, many still do not, according to the nurses interviewed. The result is that, while nurses may be exposed to IS in other parts of their education, they may not be deeply familiar or comfortable with either wireless technology or information systems concepts. Nursing informatics is a separate discipline, but nurses trained in these programs typically do not perform daily clinical tasks. At the very least, nursing schools should partner with hospitals employing UA to expose student nurses to the technology and promote developing typing skills to expedite data entry.

Additionally, technology-mediated situations often force the user to pay more attention to the technology than the person seeking service [11], the patient in this case. Thus, the technology forces the user to engage more closely with the screen than the situation or certain aspects of the task, such as patient interaction. These actions are at the expense of the needed attention the patient expects, and which the nurse is accustomed to giving. Therefore, systems hardware and software must be designed to minimize the level of disengagement of the nurse from the patient in order to access or enter data during the work process. Also, nurses must be trained in how to orchestrate the technology in the work environment so as to maintain sufficient patient interaction to establish a bond and relieve anxieties that can impede the work process. Indeed, the technology design and subsequent user training is heavily contextually based. To truly add value, it must be designed to support how, when, and where nurses engage patients and document interventions.

2. Hospital management should use technology as a recruiting and retention tool.

One in five registered nurses plans to leave the profession, and 64% state they have inadequate time with patients [7]. These alarming statistics are likely to worsen as the pool of qualified nurses dwindles and those remaining are pressured still further. However, this study suggests that UA can address some of these factors, including job stress, working conditions, morale, patient-care time constraints, and paperwork burdens. It is possible that no other current technology may be as useful, at relatively low cost, for addressing such a wide range of nursing frustrations. Hospitals that implement UA—and provide ample, supportive training in its use—may find themselves more able to recruit and retain talented nurses, a significant advantage in a fiercely competitive labor market.

3. Hospital management should create a culture, including a nurse vision statement, emphasizing the benefits and value of nurses' involvement in technology.

Nurses and hospitals benefit from understanding the value they will both receive from large-scale IS implementations. Otherwise, nurses tend to focus on their strength: patient care. According to a manager working with a large health-care system in the northeastern U.S.: "Hospital management and IS departments must make initiatives important for nurses, as well as doctors. You have to make this [technology implementation] salient to the nurses by promoting its effectiveness in decreasing administrative workload and explain how what they [the nurses] do or don't do impacts the whole care-delivery process. But you [as part of management] have to show how you are going to support them in supporting the organization... You just can't dump the technology there and expect them to use it, especially if you are replacing this chart they use to carry around with a computer on a stick...They think you are giving them more to do in attempts to make the physicians' jobs easier." Thus, nurses should be involved in physical device selection, development of interface tools, and refinement of usage processes.

4. Hospital IS departments should support development or adaptation of wearable devices and multifunction mobile carts by manufacturers to support wireless use.

"Wearables," such as handheld scanners and tablets that can be clipped onto waist belts, free nurses' hands to hold a scanner, deliver medications, or aid a patient in numerous ways. More streamlined designs for the mobile carts might make the carts more maneuverable, more able to fit between beds, and—with additional shelves or desktop space—more conducive to multiple uses. These innovations already are in place in other industries. For example, aircraft mechanics use similar configurations to fulfill their need for mobility and access to critical information at the point of service.

5. Documentation devices should be integrated to mimic the workflow (scanning, label and document printing, copying, and electronic signatures that maintain patient confidentiality) to support ease of use.

As long as nurses and registration personnel must make trips back and forth to a desk or station to generate and retrieve paperwork or ID tags, they will have a significant disincentive to use technologies supporting UA. Patient registration typically requires validating identification and insurance information, copying documents or cards, printing wristband labels, and securing signatures on documents. This time-consuming process can be expedited, while significantly reducing nurses' frustrations, when supporting devices are combined on a single mobile cart.

Task	Current Process	Prospective Process
Inpatient meal ordering	- Food administration personnel (FAP) make rounds to gather patient meal requests or patients write meal requests, reconcile physician-ordered meal restrictions, prepare requests based on food availability. - Patient may or may not receive a request, no real-time access to item availability, and lengthy manual process	- FAP use UA devices on rounds and are able to let patients know immediately, via real-time data access, whether their requests are available and meet physicians' orders. - Patients receive meals they ordered or an explanation about why they can't and faster meal service, increasing delivery quality and decreasing potential food spoilage by complying with supply to demand, thereby reducing costs.
Patient transport within hospital	- Transport personnel use walkie-talkies to communicate with nursing stations and a transport base about patient movement for records or transport instructions; requests for patient whereabouts are maintained manually. - Long transport wait times due to inefficient routing of transport personnel and equipment.	- Transport personnel, access patient data, and send requests, and related information via wireless devices. - Patients are moved quicker, and wait times are reduced, thereby improving quality of care.

Table 2. Tasks amenable to UA.

6. Hospital management should extend UA to other tasks that involve location, time, and identity or are highly information-intensive and interdependent. Table 2 provides examples of prospective processes amenable to UA.

7. Hospital management should incorporate software and hardware necessary to support automated patient and medication identification on the mobile workstations to ensure nurses are charting on the correct patient.

Manual charts typically are kept at patients' bedsides or in boxes outside of their rooms, rather than carried by nurses as they make rounds. Conversely, UA technology is mobile, and a nurse has constant access to patients' records despite location. Safeguards must be in place to ensure that nurses are charting on the right person, not to mention sterilizing the necessary hardware per intervention to prevent spreading infections as the nurse moves from one patient's location to the next or when the carts are passed to other nurses in subsequent shifts. Some hospitals' medication administration systems require barcode scanning of the ID wristband issued during registration and the medication label to ensure the correct medication is given to the correct patient. The system alerts the nurse if any scanned information is inconsistent with the prescription, such as incorrect patient, inaccurate medication or dosage, and invalid time for medication delivery. Some form of identification (such as barcoded wristband or RFID tags) that patients wear throughout their hospitals stays and that can be validated by embedded wireless security features is imperative for patient safety, and nurse and hospital liability protection.

CONCLUSION

Effectively designed UA initiatives can help allay potentially fatal errors, improve patient safety, and boost overall quality of care. Additionally, UA provides a comprehensive view of the patient's medical information, which is imperative for caregivers to effectively and efficiently service patients at every point in the care system. Caring for the patient's data is as important as caring for the patient because poor patient data quality could lead to a fatality.

The U.S. health-care industry has been a laggard when it comes to IS investments. This should change as evidence—sometimes difficult to quantify in dollars but easily identified in care- and work-quality terms—of the return on investments from implementations are publicized. Such evidence includes the 250% error reduction in the drug-ordering process that saved nearly $300,000 from 2002 to 2003 at the completely wireless El Camino Hospital in Mountain View, CA [2]. Access to information is vital to the way hospital staffs do business, and it will soon be known that tethered technologies cannot deliver the performance needed to adequately decrease administrative workloads and promote patient safety, especially for extremely mobile work forces.

It is possible that U.S. hospital administrators are comfortable with the performance of tethered systems, in which they have made substantial investments. As the status quo, tethered computing appears to have become a sustaining technology (in that it maintains the rate of historical performance improvements that stakeholders expect [1].) Therefore, for many hospital administrators, UA may be viewed as a disruptive technology (requiring process reengineering, technical restructuring, and/or systems integration). This label may not be the most effective way to foster acceptance of UA, particularly in more conservative health-care organizations. As it has been claimed: "Health care may be the most entrenched, change-averse industry in the U.S." [1].

It would be more helpful for hospitals to view these technologies not as disruptive, but as dovetailing, a convergence of the technology characteristics, organizational assets, and task performer's capabilities that disrupts the old economics of the task without disrupting the task environment or the relationship between patient and nurse [8].

Under these circumstances, UA can help reduce documentation errors and preparation time while improving information quality and nurses' working environments. Hospitals that embrace UA can increase patient safety across a wide range of caregivers, departments, and responsibilities. By collecting and delivering vital information when and where it is needed most—at the point of care—hospitals can spur their transformation into more efficient and effective and safer institutions. C

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BY WAYNE WEI HUANG,
JONATHON GREENE,
AND JOHN DAY

OUTSOURCING AND THE DECREASE OF IS PROGRAM ENROLLMENT

Students must learn to accentuate the positive in order to eliminate the negative perceptions of career opportunities in IS.

The impact of outsourcing IT jobs to low-wage economies has attracted significant public attention in recent years, particularly during the last Presidential election campaign. Some predicted that IT outsourcing would escalate at the rate of over 50% in the subsequent two years with a total of $7.8 billion shifted toward offshoring. Indeed, industry research firm Gartner Group estimated one out of every 10 IT jobs would be outsourced overseas by the end of 2004 [2].

Exposed to this news and the massive IT job downturn resulting from the dot-com bubble bursting, students of information systems (IS) and computer science (CS) became quite concerned about their job prospects after graduation, understandably fearing unemployment. These events created an impetus for IS/CS students to change their major and caused students considering IS/CS to reconsider, leading to a significant decrease in enrollment in IS and CS majors in recent years. For example, by the end of 2004, the enrollment in the IS program at the University of Florida had decreased 66% from its peak. In the computer science program at the University of Massachusetts, Amherst, the decrease was 60%, and at Ohio University it was 71%. Nationally, IS enrollments in recent years are down between 15% to 75% [3].

The gravity of the situation faced by IS programs was addressed in panel discussions at the International Conference of Information Systems—an annual meeting on IS organized by the Association of Information Systems. While recognizing the possible job loss due to offshore outsourcing, panelists questioned the accuracy of the extent of IT job losses reported in the media. They encouraged IS faculty to think of ways to deal with the negative perceptions students have developed toward IS job prospects in light of the publicity surrounding outsourcing.

Realizing the impact of offshoring on the computing community as a whole, ACM took action by forming the ACM Job Migration Task Force charged with examining this challenging and serious issue [1]. Former ACM President David Patterson [6] encouraged deeper and more creative thinking on the offshoring issue in an effort to avert young IS professionals from making "career decisions they would later regret. He called on computing educators and professionals to "share your thoughts with others."

Dealing with students' negative perceptions toward a career in IS is a critical issue for the IS discipline [3]. For some IS programs, it may even be an issue of survival. This article presents our experience at the MIS department of Ohio University where faculty addressed this issue through curriculum revision and efforts to change the negative perceptions students held about IS job prospects.

IDENTIFYING THE SOURCE

The initial step in the process was to determine the sources of information that gave students a negative view of IS as a major. By determining why students were convinced that IS graduates would not be able to find jobs due to offshoring, effective methods of addressing these factors could be developed. Interviews were conducted with a focus group of eight randomly selected IS majors taking an IS course. Students were asked if offshoring prompted concern over IS as a major. If so, they were asked about information sources that colored that picture. All of the student participants said they had negative perceptions toward outsourcing and the IS job market in the near future.

When asked for the primary information source regarding IS job loss, 46% of the students responded they heard this information from their parents, 31% from the news, and 17% from colleagues (classmates, friends, or faculty). Further, when asked about the secondary source regarding the loss of jobs, 29% of students said they learned this from friends and 21% from the news. Moreover, 88% of the students believed their parents and friends received this negative view about IS job prospects from the news.

Indeed, students did not hold firsthand information about the IS job market. Rather they received their information from three main sources: their parents, the news, and friends.

The information presented in the news can sometimes be biased, which can further be exploited by politicians to promote their political agendas. Mass media coverage of offshore outsourcing has created an unbalanced view of IS job prospects in the last 3-4 years and readers frequently read articles or viewed TV programs discussing IS job losses due to offshoring, but seldom saw opposing views. Consequently, it would not be surprising to learn that 100% of the IS majors in the focus group reported negative perceptions about IS job prospects. It is also not surprising that many IS programs have recently experienced sharp enrollment decreases.

> Dealing with students' negative perceptions toward a career in IS is a critical issue for the IS discipline. For some IS programs, it may even be AN ISSUE OF SURVIVAL.

HOW NEGATIVITY IMPACTS THE IS MAJOR

After identifying the informational sources playing a role in these perceptions, the next step is to address the unbalanced IS media coverage directly by presenting factual evidence and counterarguments.

The focus group interviews also showed that because of the "defensive behavior" of college students, they would not feel comfortable or fully convinced if IS faculty expounded on how the IS major was still a good major, even with the practice of offshoring looming in the future. A more effective way, we found, is to ask IS students to do their own research on this important issue and uncover the answers for themselves, with the support and guidance of IS faculty.

This alternative method was used in an IS course taken by junior IS majors. Students in the class were asked to form groups to do a research project on the effects of offshore outsourcing on the IS job market, and explore ways for them to deal with any possible negative impacts.

At the start of the project, the students were provided with some basic information about research methodology in terms of how to conduct a comprehensive literature review to search for papers with both positive and negative views on the IS job market. They were also instructed on how to categorize those papers based on criteria such as relevance and importance, and how to do a quality review of those research papers. The students were provided a template for the quality review process.

Student groups were also asked to present and discuss their research findings and suggested solutions with the entire class. This exercise revealed three primary findings. First, through their own research and subsequent presentations, students began to realize that some news articles written for the general public were largely biased. Indeed, the media coverage was peppered with exaggerations regarding the fear of job loss in the near future. Contrary to previous predictions, the U.S. Labor Department reported that for the 4,633 jobs moved offshore during the first three months of 2004, it was less than 2% of the layoffs for the same time period [4].

Further, students discovered some positive news about the impact of offshoring on the U.S. job market. For example, Delta Airlines, with headquarters in Atlanta, outsourced 1,000 call-center jobs to India in 2003, but the $25 million in savings from the deal allowed the firm to add 1,200 domestic reservation and sales positions. Although 70,000 computer programming jobs were lost in the U.S. between 1999 and 2003, more than 115,000 computer software engineers found higher-paying jobs during that same period. In addition, offshore outsourcing between developed and developing countries can, as a whole, benefit both countries [1].

Based on these research findings, the student groups discussed ways of dealing with possible job challenges resulting from outsourcing in the near future. The faculty guided students through a discussion about which types of IS jobs could be more easily outsourced, and which jobs would be more difficult to do so. Through constructive arguments and discussion, students realized that some IS jobs, such as basic programming, can be more easily outsourced, while higher-level jobs, such as consulting, project management, and business process analysis, are more tightly linked with core business processes and/or local customers and therefore more difficult to outsource. Indeed, integrating IS skills and knowledge could better prepare students for dealing with the possible threat of job losses due to outsourcing.

During group discussion sessions, the students were guided through an analysis of the role of IS in organizations, so that students could clearly realize that IS is critical in modern businesses. Having high-level business-related IS skills is a plus for future job hunting and career development, even with continued offshoring. As a result, through their own research, presentations, and discussions, students arrived at the conclusion that IS was important to every business, and the IS major was still an attractive major compared to other traditional disciplines. Further, when facing the challenge of IS outsourcing, one optimal solution was to double major, combining IS and another business major such as finance or accounting.

At the end of this project, a questionnaire was handed out to each student to test whether the negative perceptions about IS job prospects, outsourcing, and IS as a major had changed. The survey results indicated that students originally having negative perceptions now had more balanced views toward IS offshoring. More students (31.25%) thought that outsourcing would be beneficial to the U.S. economy in the long run than those who disagreed (25%), while the rest of the students were not sure. This was a significant difference from the outset, when 100% of the students held negative perceptions.

As a result of their own research, students no longer felt as uncertain about their own job prospects. Instead, they felt they knew how to better deal with the possible negative outsourcing on the IS job market. Most students (77%) thought the best solution was to double major within the business college. Only a few students (8%) thought that being the best student in the class was useful, 8% believed they should focus on enhancing their skills (communication skills and business skills), the final 7% thought that becoming a certified IT professional would be valuable.

When asked for additional solutions, 45% recommended broadening their horizons by improving their skills and knowledge in business, 28% recommended understanding the industry better, and 27% responded with a desire to learn and improve interpersonal skills. When asked for a third solution, 33% of the students responded with business as usual, 17% cited more emphasis on creativity skills, 17% were going to build business skills, 17% recommended not worrying about it too much, and 16% said to drop the IS major.

One encouraging outcome was that after students understood methods for dealing with the negative impact of outsourcing, no student considered dropping IS as a major. Even if their first two solutions didn't work, only 17% of the students would consider dropping IS as a major. These results indicate that with such valuable information at hand most students would be confident about choosing IS as a major.

It is interesting to note that more students agreed that the job market should be fully determined by market forces (25%) compared to those who disagreed (13%), with 56.25% students being unsure. On the other hand, 43.75% of the students still believed the government should take action to protect IS jobs from being outsourced (with 37.5% disagreeing and 18.5% not sure). This may indicate that even though students rationally thought the job market should be fully determined by market forces, it would be human nature to sometimes let self-interest supersede logic, resulting in students essentially preferring job protection. Indeed, politicians may still have an opportunity to use this offshoring issue to create media controversy in the future.

A research project designed to cause students to construct their own conclusions was largely effective in terms of facing and dealing with the negative perceptions toward the potential of future opportunities in the IS field. Enrollment data from Ohio University's MIS department by the end of 2005 showed that more than 70% of the IS majors were taking a double major with another business major. This indicates that most IS majors understand the value of broadening their major to make it more marketable.

The approach described here applies to students who are currently IS majors. The next step is to apply this approach to students who have not yet decided on a major or might be willing to consider adding IS as a major. OU's IS department has completed a major curricular revision with a focus on integrating business analysis and systems development throughout the curriculum. All these efforts have reversed the recent decline in enrollment in the IS program and have increased enrollment in the major by 30% to date. Many factors may be contributing to this reversal including the revision of the curriculum and the recent turnaround in the job market. The approach outlined here could be an additional factor applied in the introductory IS course to allow all business majors to see that IS is a viable major.

In addition, this approach may be also relevant to a CS program. For example, those students might also consider the double-major as one possible choice as well, by taking some business courses or a project management course.

CONCLUSION

The challenge created by offshore outsourcing to IS and CS education programs is so huge that many such programs, if not all, have experienced serious enrollment decreases in recent years. Professional associations in the field have realized the importance of this challenge, and have called for effective and creative methods to deal with it.

This article described one potential method that has proven successful at Ohio University. We believe this method is also easily implemented in other IS or CS programs at other universities facing the same problem. It is our belief that the IS (or CS) enrollment decrease in recent years, partially due to IS outsourcing, is a temporary phenomenon, which should be faced seriously and can be solved by using creative and effective methods.

Our suggested approach is not a solution to all the problems related to IS enrollment decreases. Other solutions, such as meeting the challenges of the global economy, skills related to entrepreneurship and project management, knowledge, and experience related to global e-commerce and m-commerce [5], and overseas internship experiences are also important [1]. It is our hope the method presented here stimulates more creative methods and provide better solutions to this important issue in the near future.

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COMMUNICATIONS OF THE ACM AUTHOR GUIDELINES

Communications of the ACM is the leading monthly print and online magazine for the elite professionals working in the computing and information technology fields. *Communications* is recognized as the most trusted and knowledgeable source of news, opinions, research, technology, and public-policy information for scientists and practitioners, and has developed a reputation over 50 years for providing the highest-quality information by and for computing professionals in industry and academia.

In July 2008, the format and editorial structure of the magazine will undergo significant change. This new editorial model has been developed to broaden the appeal of the magazine for both practitioners and researchers in industry and academia in all fields of computing and information technology, and to provide for a more international and diverse forum for ideas, practical applications of technology, and scholarly research. (For more details regarding this editorial redirection, see "CACM: Past, Present, and Future" in the January 2008 issue.) Submissions may include content that can be presented online and is distinct from material submitted for the print publication.

As a result of this new structure there will be greater competition for publishing articles in the magazine. Submissions must address topics of relevance and professional value to a very broad-based readership. It is best to remember that most readers are not experts in the author's particular discipline, but expect to get a broad perspective on computing practice and research. It is important for authors to take into account the broad composition of the ACM membership.

Communications' readers represent every known computing discipline. Among ACM's 65,000 professional members, about 65% are computing practitioners and managers and 30% are academics and researchers. The majority of readers have advanced degrees; among the professional members, 35% have master's degrees and 31% hold a Ph.D. Most members have been involved in computing for more than 12 years.

NEW EDITORIAL STRUCTURE

Beginning with the July 2008 issue, the magazine will consist primarily of six main editorial sections: **News, Viewpoints, Practice, Review Articles, Contributed Articles, and Research Highlights.** In addition, the magazine will continue to publish **Letters to the Editor** and will add a new section called **Last Byte.**

In order to manage the flow of articles for the new structure as efficiently as possible and to ensure a high degree of rigor and quality for the magazine, a new editorial board has been organized to oversee the selection of content based on this new editorial structure. The board operates both as a single unit and in more focused teams consistent with the new editorial sections.

While the selection criteria and editorial process for articles will vary by section, the board is responsible for maintaining a consistently high level of quality for all sections and for ensuring the magazine publishes across a broad spectrum of topics that appeal to an international readership of practitioners, researchers, and educators.

AUTHOR GUIDELINES

Communications will continue to welcome unsolicited submissions for publication in the magazine. Certain sections, including **Practice** and **Last Byte**, will publish articles by *invitation only.*

Submissions to the magazine must address topics of relevance and professional value and be written for a broad readership. Submissions that provide a broad perspective on computing practice and research and appeal to a larger segment of the ACM membership and computing community will be given priority over articles that require a significant level of knowledge of specific subject-matter expertise.

All submissions are reviewed by the *Communications* Editorial Board and Editor-in-Chief, who reserve the right to accept or reject any and all submissions at their discretion. The Editor-in-Chief can be contacted at eic@cacm.acm.org. Manuscripts for all editorial sections are expected to adhere to the following guidelines:

News publishes a selection of brief news updates and in-depth news articles (up to 2,000 words) on a range of U.S. and international topics in computing, information technology, and public-policy issues. *Communications*' News department employs full-time professional science and technology writers and an expanding network of freelance writers to provide the most current news related to computing and related topics for publication in the print and online editions of the magazine.

If you are a professional science or technology writer or have written a current news article on a topic you believe is appropriate for the computing community, please send a brief email message with your submission to News@cacm.acm.org.

Viewpoints is dedicated to opinions and views that pertain to issues of broad interest to the computing community, typically, but not exclusively, of a nontechnical nature. Controversial issues will not be avoided but be dealt with fairly. Authors are welcome to submit carefully reasoned "Viewpoints" in which positions are substantiated by facts or principled arguments. Moreover, this section will periodically host editorial debates in a Point/Counterpoint format in which both sides of an issue are represented.

Authors interested in proposing a Viewpoint article or Point/Counterpoint debate should first submit their ideas in a short (up to 600 words) summary encapsulating their view(s). Full-length Viewpoint columns should consist of up to 1,800 words, include a small number of references (generally no more than 10), and be submitted to: http://www.cacm.acm.org/submissions.

Contributed Articles cover the wide and abundant spectrum of the computing field—its open challenges, technical visions and perspectives, educational aspects, societal impact, significant applications and research results of high significance and broad interest. Following the roots of *Communications*, these submissions are peer-reviewed to ensure the highest quality. Topics covered must reach out to a very broad technical audience. While articles appearing in an *ACM Transactions* journal are aimed at a specialized audience, articles in *Communications* should be aimed at the broad computing and information technology community.

A Contributed Article should set the background and provide introductory references, define fundamental concepts, compare alternate approaches, and explain the significance or application of a particular technology or result by means of well-reasoned text and pertinent graphical material. The use of sidebars to illustrate significant points is encouraged.

Full-length Contributed Articles should consist of up to 4,000 words, contain no more than 25 references, 3-4 tables, 3-4 figures, and be submit ted to: http://www.cacm.acm.org/submissions.

Submissions to the Contributed Articles section should be accompanied by a cover letter indicating:

- Title and the central theme of the article;
- Statement addressing why the material is important to the computing field and value to the *Communications* reader; and,
- Names and email addresses of three or more recognized experts who would be considered appropriate to review the submission.

Authors are strongly encouraged to pre-submit a one-page summary (with a cover letter as described here) to get editorial feedback before submitting a full-length article.

Review Articles describe new developments of broad significance to the computing field and highlight unresolved questions and future directions. Unlike an article in *ACM Computing Surveys*, which provides an in-depth introduction to a technical area, a review article in *Communications* should offer a high-level perspective on a technical area.

Authors are encouraged to begin the process by making a pre-submission inquiry, which should include a proposed title, abstract, and a few key references. Proposals will be reviewed and prospective authors will either receive a formal invitation to prepare a full manuscript (note: an invitation to write an article does not guarantee its publication) or a rejection based on the suitability of their proposal for publication in the magazine. Authors who receive a rejection, but are convinced of the importance of their work, may submit a complete manuscript for consideration by the magazine's Editorial Board.

All Review Articles undergo a thorough peer-review process. Submissions should consist of up to 6,000 words, include an abstract and introduction, up to 40 references, and be submitted to: http://www.cacm.acm.org/submissions.

Practice targets professionals in the software industry with an emphasis on software engineering. Articles published in this section frame and define technical problems and challenges ahead while helping readers sharpen their own thinking and ability to pursue innovative solutions. Practice does not focus on industry news or the latest solutions. Rather, articles explore disruptive technologies that are just on the verge of breaking through.

This section highlights problems that are likely to arise and poses questions that software engineers should be thinking about while dissecting industry issues that matter most and examines the challenges faced by software architects, project leaders, IT managers, and corporate decision makers.

Submissions to this section are by *invitation only*. Detailed submission guidelines will be forwarded to invited authors.

Research Highlights provides readers with a collection of outstanding research articles, selected from the broad spectrum of computing-research conferences. Submissions are first nominated by Editorial Board Members or Approved Nominating Organizations and are then subject to final selection by the Editorial Board. Authors are then invited to submit their article, after they have rewritten and expanded their scope as appropriate for the broad readership of *Communications*.

It is important to note that publication in *Communications*, a computing-technology and science magazine, does not conflict with publication in archival journals. Articles in archival journals are typically expanded versions of conference publications, while *Communications* aims to publish somewhat shorter and higher-level versions of these articles.

Each selected Research Highlights article is preceded by a one-page (700–800 words) summary.

Technical Perspective essays provide readers with an overview of the underlying motivation, the important ideas of the featured research, and its scientific and practical significance. Technical Perspective articles will be written by noted experts in the field addressed by the Research-Highlight article and will be invited by the Editorial Board.

Full-length Research Highlights should consist of no more than eight pages according to the CACM Research Highlights Template (http://www.acm.org/publications/cacm/guidelines/rht-mplate) and contain no more than 25 references. *Authors should note this template is provided as a helpful measuring tool only; it does not reflect camera-ready copy.*

Papers should be submitted to: http://www.cacm.acm.org/submissions.

Letters to the Editor consists of comments on articles published in both the print and online editions of the *Communications*, as well as selections or contributions from various blogs published by ACM as appropriate.

Submitted letters should not exceed 500 words and should include the contributor's name, email address, and postal address. Due to limited space, *Communications* cannot publish all submitted letters in the printed magazine. Whenever possible, high-quality letters will be posted on the *Communications* Web site:

http://www.cacm.acm.org/.

Preference will be given to feedback that begins new discussions, adds significant new points to previous discussions, or is highly time-sensitive. Send letters to letters@cacm.acm.org.

Last Byte consists of lighter-fare content that will appear as both regularly appearing columns, such as Q&As, futurist articles dealing with computing, and mathematical puzzles for those who like a good challenge. If you have an idea for a one-time or regularly appearing Last Byte contribution that you believe is appropriate for the computing community, please send a brief email message with your idea to LastByte@cacm.acm.org.

GENERAL GUIDELINES

Manuscript Preparation

The preferred file type for manuscripts, with the exception of Research Highlights, is MS Word or RTF, but PDF is also acceptable. Research Highlights papers should be submitted as LaTeX files; a template has been provided to help gauge length restrictions (http://www.acm.org/publications/cacm/guidelines/rhtemplate). Use of this template does not indicate camera-ready copy. All material submitted to *Communications* is edited and copyedited.

All files should reflect the following guidelines:

Headlines: Article titles should be inviting and manageable. Authors should consider using 6–7 words at most and avoid the use of colons if possible.

References: References (see specific section for citation limits) to previous work should be included at the end of the article. References must be ordered alphabetically by first author and numbered. All listed references must be referred to in text by their corresponding number.

Artwork: Clear sketches and accurate graphs are sufficient for initial submissions. Upon acceptance of the article, authors will be given instructions regarding the submission of final artwork. Any artwork derived from sources other than the author's own must be accompanied by an appropriate letter of permission and source citation. It is the author's responsibility to obtain such copyright permission and credit wording.

Accepted Submissions: Upon article acceptance, *Communications* editors provide authors with additional information regarding final electronic submissions.

The lead author for each manuscript will be contacted once the article has been slated for publication. Once scheduled, *Communications* editors will edit the article for substance and presentation. All articles will also be copyedited to conform to *The Chicago Manual of Style* (University of Chicago Press), as well as *Communications'* house style. All tables and figures are redrawn for consistency by a graphic artist using the drafts supplied. Authors should provide concise titles and caption copy.

Articles published in *Communications* will run in a two-column or three-column format. Therefore, authors must make sure any programming code or equations included in the manuscript are set for correct line breaks, indentations, and punctuation. Code that runs more than 35 characters wide will be pulled from text and reset as a figure, in which case a figure caption must be supplied.

Supporting Online Material: Informational resources for the online presentation of articles in every editorial section of *Communications* are welcome. These materials may include but are not limited to additional tables; figures; URLs for online references; video files; audio files; a list of print references; PowerPoint presentations; and other related materials and links. Information regarding submission of this material is available upon acceptance.

ACM POLICIES

Articles that have been submitted simultaneously to other magazines or journals will be declined outright and not reconsidered.

Authors are encouraged to review ACM's PlagiarismPolicy(http://www.acm.org/publications/policies/plagiarism_policy) and ACM's Copyright Transfer Form (http://www.acm.org/publications/copyright_form) prior to submitting material to *Communications.* C

PAUL WATSON

Barry University
Assistant Professor

The Department of Mathematics and Computer Science at Barry University invites applications for a faculty position in Computer Science with the rank of Assistant Professor, starting in Fall 2008. More information at http://euclid.barry.edu/positions.htm. E-mail mathcs@mail.barry.edu. Barry is an EOE.

Colorado State University
Web Developer

CSU's College of Engineering seeks a part time administrative professional for web design. For full job description and requirements, see www.engr.colostate.edu/ens/jobs/. Full consideration deadline is May 5, 2008. Limited interview travel funds. CSU is an EO/AA employer.

KAIST
Tenure-track faculty

The Department of Computer Science at KAIST, the top Science & Engineering University in Korea, invites applications for multiple tenure-track faculty positions at all levels. Applicants are welcome in all major fields of computer science, computer engineering and their interdisciplinary areas. Applicants must have a Ph.D. or an equivalent degree in computer science or a closely related field by the time of appointment. Strong candidates who are expected to achieve the Ph.D. degrees within a year can be offered our appointment. Applicants must demonstrate strong research potential and commitment to teaching. KAIST offers a competitive start-up research fund and joint appointment with KAIST Institutes, which will expand opportunities in interdisciplinary research and funding. KAIST attracts nationwide top students pursuing B.S., M.S., and Ph.D. degrees. The teaching load is three hours per semester. KAIST also provides housing for five years. KAIST is committed to increasing the number of female and non-Korean faculty members.

Applicants should submit the application form and CV along with the required documents to Head, Department of Computer Science (email: kschoi@cs.kaist.ac.kr) or Chair, Search Committee, Department of Computer Science (email: kywhang@cs.kaist.ac.kr). For more information on available positions, please visit the KAIST website: http://cs.kaist.ac.kr/department/recruit.htmdepartment/recruit.htm.

Katholieke Universiteit Leuven
Professor in Computer Science

Tenure-track vacancy in Computer Networks

The Department of Computer Science, faculty of Engineering announces a vacancy for a full time tenured or tenure-track position in the field of computer networks, starting October 1st 2009.

Candidates should have substantial and internationally recognized research expertise in the area of software for traditional computer networks (internet, intranet) as well as for new platforms (for instance sensor networks). This research includes network and transport protocols, typically realized within the operating system, and session and application protocols, typically realized within a middleware. Security of and within network software is an important field of research. There is also a growing interest in management aspects such as the management of software configurations and the generation and enforcement of policies.

The candidate will attract and lead national and international research projects. He/she should have demonstrable research and didactical experience in the domain of software for computer networks. The candidate is expected to take a leading role in attracting and guiding PhD students and to network with leading foreign institutions (inside/outside EU).

The candidate will teach courses on computer networks in the master programs of engineering (computer science), the master of informatics, the bachelor of engineering and/or the bachelor of informatics.

All candidates must have a PhD in Sciences or Applied Sciences. Initially candidates can teach in English. They must commit themselves to learning Dutch, so that they are able to teach in Dutch after a trial period.

The appointment will be made in the rank of assistant professor or higher, depending on the qualifications of the candidate. The K.U.Leuven is an equal opportunity employer.

Inquires about the position should be directed to Pierre Verbaeten, head of the department of Computer Science (pierre.verbaeten at cs.kuleuven.be).

NEC Laboratories America
Research Staff Positions

NEC Laboratories America, a premier research facility of NEC Corporation, has multiple openings in the Systems Architecture Department in Princeton, NJ. We invite applications from exceptional candidates (senior-level or junior-level) for research staff and associate research staff positions. The Systems Architecture department's mission is to innovate, design, evaluate and deliver system architecture (hardware and software) solutions to realize high-performance systems.

Candidates for the RSM position must have a PhD in CS, CE, or EE, strong research record and excellent credentials in the international research community. Applicants must be able to propose and execute innovative research projects, including prototyping effort that leads to demonstration in an industry environment. Applicants must demonstrate competency in one or more of the following Systems Architecture areas: parallel programming models and run-times, parallel hardware architectures, system software for chip-level multiprocessors (including operating systems, server/domain-specific middleware), with a focus on high performance.

Candidates for the ARSM position must have at least a MS in CS, CE, or EE, with a strong motivation and skill set to prototype/transfer innovative research results into industry prac-

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◆ ACM accepts recruitment advertising under the basic premise the advertising employer does not discriminate on the basis of age, color,race, religion, gender, sexual preference, or national origin. ACM recognizes, however, that laws on such matters vary from country to countryand contain exceptions, inconsistencies, or contradictions. This is true of laws in the United States of America as it is of other countries. Thus ACM policy requires each advertising employer to state explicitly in the advertisement any employer restrictions that may apply with respect to age, color, race, religion, gender, sexual preference, or national origin. (Observance of the legal retirement age in the employer's country is not considered discriminatory under this policy.) ACM also reserves the right to unilaterally reject any advertising. ACM provides notices of positions available as a service to the entire membership. ACM recognizes that from time to time there may be some recruitment advertising that may be applicable to a small subset of the membership, and that this advertising may be inherently discriminatory. ACM does not necessarily endorse this advertising, but recognizes the membership has a right to be informed of such career opportunities. ◆

tice. Expertise in one or more areas of Systems Architecture is desirable. Strong interest and aptitude for research is necessary.

NEC Laboratories America Inc. is part of NEC Corporation's global network of research laboratories. We conduct research in support of NEC's US and global businesses. Our research program covers areas that reflect the scope and breadth of NEC's Business Units. Ranked as one of the world's top patent-producing companies, NEC Corporation delivers tailored solutions in the key fields of computers, networking and internet systems, by integrating its technical strengths in IT and networks, and by providing advanced semiconductor solutions.

For more information, please visit http://www.nec-labs.com/. Interested applicants should send their resume and a short description of research interests to recruit@nec-labs.com and reference "Systems Architecture" in the subject line. EOE/AA/MFDV

Pennsylvania State University
Information Sciences & Technology

Penn State York invites applications for a faculty position in Information Sciences and Technology (Instructor multi-year appointment; 36 weeks). Begin August 2008. Teach in one or more of the following IST subjects: database, software development, networking, enterprise systems, emerging technologies, project management, security, HCI and/or software integration. Master's degree in IST or related discipline is required. Industrial experience is welcome. To learn more about the campus, visit http://www.psu.edu/ur/cmpcoll.html. To learn about the position and how to apply, visit http://www.psu.jobs/Opportunities/Opportunities.html and follow the "Faculty" link. AA/EOE.

Shanghai Jiao Tong University
Computer Science Tenure Track Faculty Positions

The Department of Computer Science and Engineering at Shanghai Jiao Tong University invites applications for 8-10 tenure-track faculty positions at all levels, beginning this Fall, 2008. The preferred interests include: (1) Database and Information Retrieval? (2) Networking? (3) Data Mining? (4) Speech Recognition? (5) Video Coding? (6) Machine Learning and Translation? (7) Natural Language Processing? (8) Computer Architectures?and (9) Algorithms. The Department of Computer Science and Engineering offers both undergraduate and postgraduate (Master and Ph.D) levels, and has excellent computing resources, well-equipped teaching and research facilities and support. Information about the Department can be obtained at http://www.cs.sjtu.edu.cn/English/english_index.htm

Applicants should have a Ph.D. degree in Computer Science, Computer Engineering, or related fields, and a strong interest in research and teaching. A solid track record in research is essential. Please send an application letter; curriculum vitae including e-mail address, teaching statement, research statement; copy of university diplomas; and three current letters of recommendation to: Search Committee (Secretary Xun Liu), Department of Computer Science and Engineering, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai, 200240, China. email: search@cs.sjtu.edu.cn, phone: +86-21-34204398, fax: +86-21-34206609. We are accepting applications now and applications will be accepted until the positions are filled. The Shanghai Jiao Tong University is an equal opportunity employer.

ACM's calendar policy is to list open computer science meetings that are Sponsor by ACM, sister societies, or other scientific, technical or educational tax-exempt organizations. Educational seminars, institutes, and courses are not included due to space limitations. Listings for conferences NOT Sponsor by ACM should include the title of the conference, Sponsor organization, a contact name and full address. Phone number, email address, URL and/or fax numbers are optional. Please address to: Calendar Items, CACM, 2 Penn Plaza, New York, NY 10121-0701; fax: (212) 869-0481; email: calendar@acm.org. For Conferences and Workshops Sponsor or cosponsored by ACM, the calendar listing should be included with the initial documents submitted for approval to ACM. All requests for ACM sponsorship or cooperation should be addressed to: Conference Coordinator, ACM Headquarters, 2 Penn Plaza, New York, NY 10121-0701; (212) 626-0602; email: SIGS@acm.org. The Technical Meeting Request Form (TMRF) for this purpose can be obtained from the Conference Coordinator. The TMRF should be submitted at least nine months in advance of the event to ensure time for processing the approval and to accommodate lead time for CACM listings.

The ACM calendar and calls can also be accessed on-line via the URL http://www.acm.org/events/coe.html. For further details please contact webmaster@acm.org

Conferences receiving ACM sponsorship/co-sponsorship or cooperation are noted in boldface.

2008

June 14-16
SPAA 08: 20TH ACM SYMPOSIUM ON PARALLELIS IN ALGORITHMS AND ARCHITECTURES Munich, Germany, Sponsored: SIGACT, SIGARCH, Contact: Freidhelm Meyer auf der Heide, Phone: 49-5251-60-6480, Email: fmadh@uni-paderborn.de

June 16-20
JCDL '08: JOINT CONFERENCE ON DIGITAL LIBRARIES Pittsburgh, PA, Sponsored: SIGWEB, SIGIR, Contact: Ronald Larson, Phone: 412-624-5139, Email: rlarsen@pitt.edu

June 17-20
THE 6TH INTERNATIONAL CONFERENCE ON MOBILE SYSTEMS, APPLICATIONS AND SERVICES Breckenridge, CO, Sponsored: SIGMOBILE, Contact: Dirk C Grunwald, Phone: 303-492-0452, Email: grunwald@cs.colorado.edu

June 18-20
IEA/AIE-2008: 21ST INTERNATIONAL CONFERENCE ON INDUSTRIAL, ENGINEERING, & OTHER APPLICATIONS OF APPLIED INTELLIGENT SYSTEMS Wroclaw, Poland, Contact: Moonis Ali, Email: ma04@txstate.edu

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June 19-21
19TH ACM CONFERENCE ON HYPERTEXT AND HYPERMEDIA Pittsburgh, PA, Sponsored: SIGWEB, Contact: Dr. Peter Brusilovsky, Phone: 412-6249404, Email: peterb@pitt.edu

June 20-21
GRAPHICS HARDWARE Sarajevo, Bosnia, Contact: Michael C. Doggett, Phone: 508-303-3900, Email: Michael.doggett@amd.com

June 21-25
THE 35TH ANNUAL INTERNATIONAL SYMPOSIUM ON COMPUTER ARCHITECTURE Beijing, China, Sponsored: SIGARCH, Contact: Kai Li, Phone: 609-258-4639, Email: li@cs.princeton.edu

June 23-26
WOSP '08: WORKSHOP ON SOFTWARE AND PERFORMANCE Princeton, NJ, Phone: 908-615-4524, Email: beto5599@yahoo.com

June 23-27
HPDC '08: INTERNATIONAL SYMPOSIUM ON HIGH PERFORMANCE DISTRIBUTED COMPUTING Boston, MA, Contact: Manish Parashar, Phone: 732-445-5388, Email: parashar@caip.rutgers.edu

June 30- July 2
ITiCSE '08: 13TH ANNUAL CONFERENCE ON INNOVATION AND TECHNOLOGY IN COMPUTER SCIENCE EDUCATION Madrid, Spain, Contact: June Amillo, Phone: 349-133-67427, Email: amillo@fi.upm.es

July 1-3
AIMS08: INTERNATIONAL CONFERENCE ON AUTONOMOUS INFRASTRUCTURE, MANAGEMENT AND SECURITY 2008 Bremen, Germany, Contact: Juergen Schoenwaelder, Email: j.schoenwaelder@jacobs-university.de

July 2-4
Distributed Event-Based Systems Conference Rome, Italy, Contact: Baldoni Roberto, Email: baldoni@dis.uniroma1.it

July 3-4
EUROPEAN CONFERENCE ON INTERACTIVE TELEVISION 2008 Salzburg, Austria, Contact: Manfred Tscheligi, Email: Manfred.tscheligi@sbg.ac.at

July 7-9
INTERNATIONAL CONFERENCE ON CONTENT-BASED IMAGE AND VIDEO RETRIEVAL Niagra Falls, Canada, Contact: Jiebo Luo, Phone: 585-722-7139, Email: jiebo@ieee.org

July 7-11
EUROPEAN CONFERENCE ON OBJECT ORIENTED PROGRAMMING Paphos, Cyprus, Contact: Jan Vitek, Email: jv@cs.purdue.edu

July 8-12
ACM CONFERENCE ON ELECTRONIC COMMERCE Chicago, IL, Contact: Lance Fortnow, Phone: 847-347-3872, Email: lance@fortnow.com

Risks of Neglecting Infrastructure

The September 2006 column ("The Foresight Saga") discussed failures in critical infrastructures due to lack of foresight in backup and recovery facilities. This column considers some of the causes and effects of another common kind of missing foresight: inadequate infrastructure maintenance. Civilization and infrastructure are intimately intertwined. Rising civilizations build and benefit from their infrastructures in a "virtuous cycle." As civilizations decline, their infrastructures decay—although unmaintained vestiges, such as roads and aqueducts, may outlive them.

Dependence on critical infrastructures is increasing worldwide. This is true not only of information systems and network services, but also of energy, water, sanitation, transportation, and others that we rely on for our livelihoods and well-being. These critical infrastructures are becoming more interrelated, and most of them are becoming heavily dependent on information infrastructures. People demand ever more and better services, but understand ever less about what it takes to provide those services. Higher expectations for services are often not reflected in higher standards for infrastructure elements.

Engineers know that physical infrastructures decay without regular maintenance, and prepare for aging by requiring inspections and repairs. Proper maintenance is generally the cheapest form of insurance against failures. However, it has a definite present cost that must be balanced against the unknown future cost of possible failures. Many costly infrastructure failures could have been prevented by timely maintenance. U.S. engineers have been warning about underinvestment in infrastructure maintenance for at least a quarter-century, but the problem is not limited to the U.S.

Neglect is the inertially easy path; proactive planning requires more immediate effort, resources, and funding. Creating maintainable systems is difficult and requires significant foresight, appropriate budgets, and skilled individuals. But investments in maintainability can reap enormous long-term benefits, through robustness to attack, simplified maintenance, ease of use, and adaptability to new needs.

Although computer software does not rust, it is subject to incompatibilities and failures caused by evolving requirements, changing environments, changes in underlying hardware and software, changing user practices, and malicious exploitation of discovered vulnerabilities. Therefore, it requires maintenance. Yet the costs of maintenance are often ignored in the planning, design, construction, and operation of critical systems. Incremental upgrades to software are error-prone. Patchwork fixes (especially repeated patches) further detract from maintainability. Software engineers receive little training in preparing for software aging, in supporting legacy software, or in knowing when and how to terminate decrepit legacy systems.

Insecure networked computers provide vandals easy access to the Internet, where spam, denial-of-service attacks, and botnet acquisition and control constitute an increasing fraction of all traffic. They directly threaten the viability of one of our most critical modern infrastructures, and indirectly threaten all the infrastructures connected to it.

As the example of New Orleans after Hurricane Katrina shows, failure of a critical infrastructure (the levees) can cascade into others. The very synergies among infrastructures that allow progress to accelerate are a source of positive (amplifying) feedback, allowing initial failures to escalate into much larger long-term problems involving many different infrastructures. Ironically, such "positive" feedback often has negative consequences. Katrina should also remind us that remediating after a collapse often involves many secondary costs that were not foreseen. The more different infrastructures that fail concurrently, the more difficult it becomes to restore service in any of them. Restoring a lost "ecosystem" costs much more than the sum of the costs of restoring each element separately.

Chronic neglect of infrastructure maintenance is not a simple problem, and does not have a simple solution. Technical, economic, social, and political factors intertwine; adequate solutions must involve both the public and private sectors. People who use these infrastructures must appreciate the importance of maintaining them. People who understand sources of the fragilities, vulnerabilities, and decay in our critical infrastructures have a responsibility to educate decision makers and the public about these risks. C

Jim Horning (horning@acm.org) is Chief Scientist of SPARTA's Information Systems Security Operation; see his blog at http://horning.blogspot.com.
Peter G. Neumann moderates the ACM Risks Forum (www.risks.org).

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