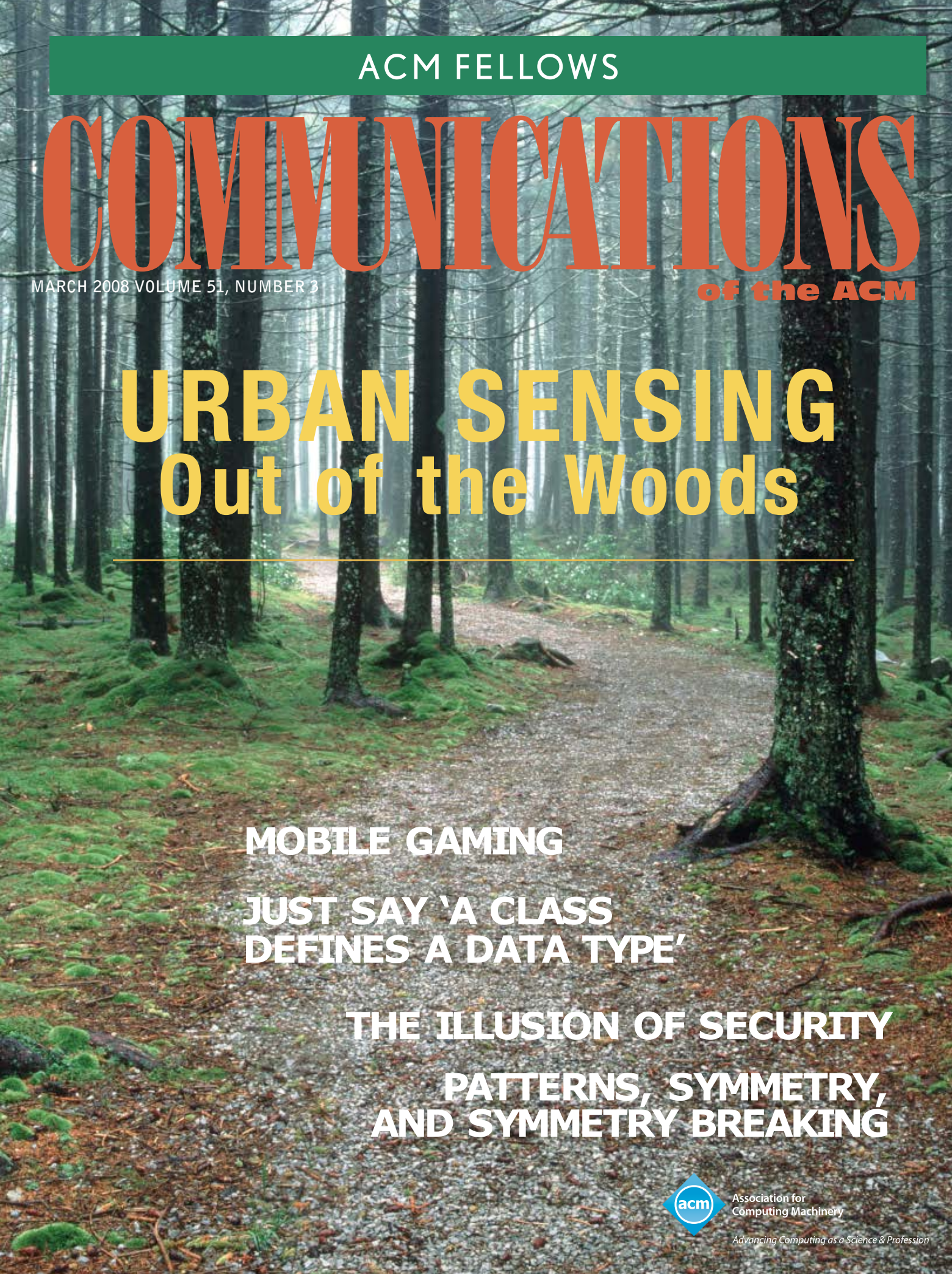

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COMMUNICATIONS

MARCH 2008 VOLUME 51, NUMBER 3

of the ACM

URBAN SENSING
Out of the Woods

MOBILE GAMING

JUST SAY 'A CLASS DEFINES A DATA TYPE'

THE ILLUSION OF SECURITY

PATTERNS, SYMMETRY, AND SYMMETRY BREAKING

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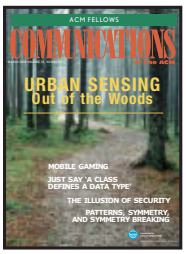

When embedded network sensing shifted from the laboratory to the natural environment, it was done under the meticulous design of scientists. Computer nodes embedded in the physical world would observe ecosystems, collecting field data intended to give researchers an unprecedented window into how nature works. But like most technologies with great repurposing potential, networked sensing is moving at a far faster and fortuitous pace into the urban landscape, driven more by opportunism than real science.

In this month's cover story "Urban Sensing: Out of the Woods," Dana Cuff, Mark Hansen, and Jerry Kang of UCLA trace how urban sensing will be "unleashed" in city settings through the proliferation of cell phones, GPS technologies, and RFID tags. Collecting data on citizens brings great opportunities as well as a host of ethical and privacy concerns. The authors call for a collaborative effort among scientists, artists, urbanists, and business people to establish a trustworthy infrastructure for city-based networked sensing.

In other technologies and services spawned by cell phones and mobile devices, Junglas and Watson demonstrate the differences between location-tracking and location-aware services. And Soh and Tan examine how the mobile games market's enormous business opportunity also comes with a significant threat to the incumbent billion-dollar gaming industry.

Liping Zhao offers a word of advice for today's programmer: The next time you design a program, think carefully about which symmetries to keep and which ones to break, and why. In "Applications of Critical Thought for IT Professionals," Bernd Carsten Stahl and Carole Brooke offer some "critical" guidelines for IT professionals that require effort, resources, and the courage to question oneself.

Two articles this month focus on security weaknesses among business practices and the global user community. Wright et al. present a fictional scenario of daily life in a world networked through ambient intelligence. The year is 2018 and the story unravels a tale of corporate ethical choices. In the end, they wonder, is this world of 10 years hence really any different from today's? Meanwhile, Larose, Rifon and Enbody speculate how to encourage Internet users to assume more responsibility for protecting themselves online.

In this month's "Viewpoint," Chenglie Hu argues the study of data types is crucial for learning programming. Novices, he says, who do not learn data types the correct way will face great difficulty trying to learn object-oriented programming. Phillip Armour highlights the pitfalls of "accurately" estimating software projects in "The Business of Software." And, on page 22, ACM is pleased to announce its newly inducted ACM Fellows.

Diane Crawford

Editor

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Managing Editor: Thomas E. Lambert
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News Track

Mixed Indicators

The National Science Board says leading science and engineering indicators tell a mixed story regarding U.S. achievements in science, R&D, and math in international comparisons. As reported in NetWorkWorld, U.S. schools continue to lag behind their internationally counterparts in science and math education. On the flip side, the U.S. leads in patent development and is the largest R&D-performing country in the world, investing $340 billion in future-related technologies. While the report is massive, the NSB came up with 13 prime observations, or what it calls the leading Science and Engineering Indicators 2008 (www.nsf.gov/news/news_summ.jsp?cntn_id=110984). Along with the educational signals, the report also notes U.S. firms increased the number of people employed in R&D jobs *outside* the U.S. by 76% and employment within the U.S. by 31%, while U.S. subsidiaries of foreign firms increased their U.S. R&D employment by 18%. Moreover, the U.S. remains the leading producer in high-tech manufacturing and knowledge-intensive services, but several Asian countries, led by China, are rapidly increasing their global share.

Robot-Propelling Thoughts

The robotics world registered a significant advancement in brain-machine interface technology last January when a 12-lb monkey climbed onto a treadmill at Duke University and began walking at a steady pace, prompting a 200-lb humanoid robot on a treadmill in Kyoto, Japan to do the same. It was the first successful attempt at using brain signals to make a robot walk, thus producing bountiful implications, reports the *New York Times*. Miguel A.L. Nicolelis headed up the Duke experiment that robotics experts worldwide called an exciting and important advancement in brain-machine interfacing. "It's one small step for a robot and one giant leap for a primate," said Nicolelis after the test. The monkey, trained to walk on two legs, had electrodes implanted in her brain to record the activity of the 250–300 neurons that fired as she walked. These signals were fed into the computer and transmitted via the Net to CB, the Computational Brain robot at the ATR Computational Neuroscience Laboratories in Japan, chosen for its extraordinary ability to mimic human locomotion. These experiments represent the first step toward brain-machine interfacing that may someday may permit paralyzed people to walk by directing devices with their thoughts.

Global Database

The FBI is coordinating global allies in the "war against terror" to build an international database to hunt major criminals and terrorists. The "Server in the Sky" program would require cooperation among police forces in Australia, Canada, New Zealand, U.S, and the U.K. to share more than the current practice of sending fingerprint faxes across the Atlantic. The *Guardian* reports the working group, called the International Information Consortium, will strategize on how to best share biometric measurements, irises or palm prints, as well as finger-

News Track

prints and other personal information likely to be exchanged through the network. The FBI proposes three categories of suspects for the shared system: internationally recognized terrorists and felons; major felons and suspected terrorists; and subjects of terrorist investigations or criminals with international links. An FBI spokesperson says the agency hopes to see a pilot project up and running by mid-year.

Know the Enemy, and Yourself

In other defense news, a Pentagon chief acquisition official has asked the U.S. Defense Science Board to organize a "Task Force on Understanding Adversaries." The board, an advisory group to the Office of the Secretary of Defense, was established 50 years ago and is known for its respected reports on science and technology issues. The task force will be responsible for increasing the understanding "of adversaries, their operating environment, and the relevant host population—to devise effective terrorist and insurgent countermeasures, and support strategic communications." The Pentagon memo prompted a Wired.com blog that wondered how science and technology experts would approach issues outside their primary field, in this case, the social sciences. While Board chairs have been thinking of recruiting social scientists to join what is typically a hard-science-heavy organization, observers wonder if these diverse groups can come to any meaningful recommendations, recalling an ill-fated attempt to recruit social scientists during the Vietnam War era. Said one blogger: "If the Pentagon is really serious about gaining expertise in the social sciences, why not have a Defense Social Science Board?"

Body Electric

Scientists from the Lawrence Berkeley National Laboratory believe they have discovered a much more efficient way to use silicon to convert body heat into electricity for use in a variety of products ranging from cars to portable electronics. According to *TG Daily*, the concept of converting waste heat into electricity isn't new but never really materialized due to efficiency obstacles. Now, researchers using what they describe as "rough" silicon nanowires created in a process of "electroless etching" may increase the conversion efficiency by a factor of 100. While the research is far from complete, the scientists believe potential applications include the Department of Engery's hydrogen fuel cell-powered Freedom Car and personal power jackets that could use heat from the human body to recharge cell phones, iPods, and other electronic devices.

Orbital Games, Virtually

NASA is exploring the possibility of developing a massively multiplayer online (MMO) game for students that would simulate real NASA engineering and scientific missions. NASA believes the game would help find and inspire the next generation of scientists and engineers needed to fulfill its vision of space exploration, reports BBC News. The agency recently issued an RFI from organizations interested in developing the platform. The document calls for a game engine with powerful physics capabilities that would support accurate in-game experimentation and research, saying "A NASA-based MMO could provide opportunities for students to investigate science, technology, engineering, and mathematics career paths while participating in engaging game play." For more, see http://procurement.nasa.gov/cgi-bin/eps/synopsis.cgi?acqid=128415. C

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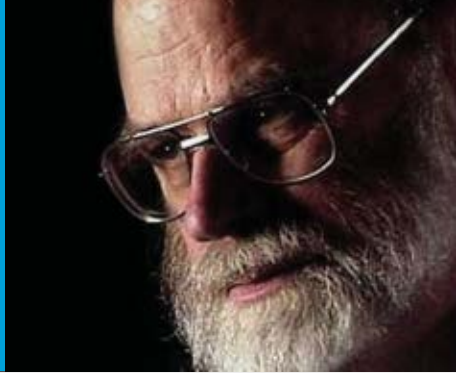
Tribute to Honor Jim Gray

May 31, 2008
University of California, Berkeley



A Tribute Honoring Jim Gray:
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Zellerbach Hall, UCB
9:00am – 10:30am

Speakers:

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Pauline Boss
Mike Olson
Paula Hawthorn
Mike Harrison
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Ed Lazowska
Mike Stonebraker
David Vaskevitch
Rick Rashid
Stuart Russell

All are welcome.
Registration is not required.

Technical Session

Wheeler Hall, UCB
Please see website for session times.

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Bruce Lindsay
John Nauman
David DeWitt
Gordon Bell
Andreas Reuter
Tom Barclay
Alex Szalay
Curtis Wong
Ed Saade
Jim Bellingham

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Technical Session registration and additional information:

http://www.eecs.berkeley.edu/ipro/jimgraytribute

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The Inaccurate Conception

Some thoughts on the accuracy of estimates.

'estimate \'es-tə-ˌmāt\ *vt* [**L** *aestimatus*, pp. of *aestimare* to value, estimate] **1** archaic **a:** ESTEEM **b:** APPRAISE **2 a:** to judge tentatively or approximately the value, worth, or significance of **b:** to determine roughly the size, extent, or nature of **c:** to produce a statement of the approximate cost of

Merriam-Webster's Dictionary

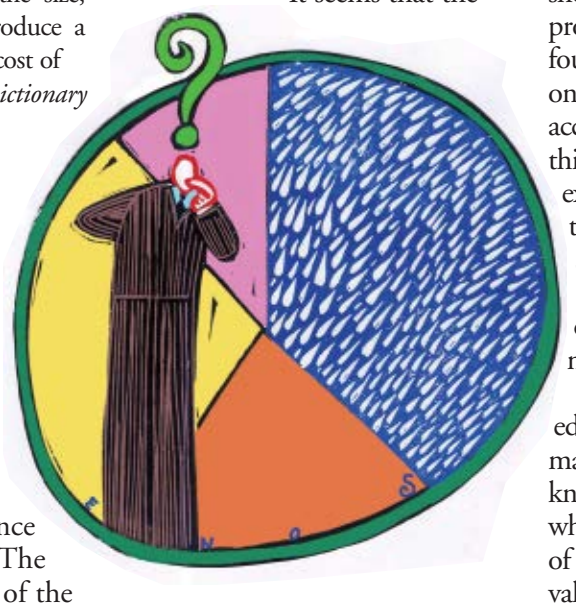
The pursuit of an "accurate estimate" for a system development project is an article of faith among project planners and managers. Methods, tools, approaches, and formulae to devise the accurate estimate are the subject of articles, conference presentations, and books. The fact that the juxtaposition of the words "accurate" and "estimate" produces an oxymoron does not seem to deter people from the quest for what is clearly a contradiction in terms.

Are we looking for the wrong estimation criterion?

Whether Forecast?

When a weather forecast indicates a 40% chance of rain and it rains on you, was the forecast accurate? If it doesn't rain on you, was the forecast inaccurate? Thought of in these terms, the concept of accuracy takes on a different meaning.

It seems that the fact it does or does not rain on you is not a particularly good measure of the accuracy of the rain estimate.



RANDALL ENOS

The Cone of Uncertainty

In his excellent book, *Software Estimation: Demystifying the Black Art* [3], Steve McConnell disinterred the "Cone of Uncertainty" originally shown years ago by Barry Boehm [2].

The Cone of Uncertainty describes the typical range of attainable accuracy of a software project estimate at different times in the project life cycle. Figure 1 shows that in the early stages of the project, the range might be from four times the final actual result to one quarter of the actual. Not very accurate, is it? Both authors assert this is about the best you can expect to do at that point in time, though the actual range is highly situational. That is, we could do worse than 4X–0.25X, but we can't realistically expect to do much better. But why is this true?

Certainty comes from knowledge of something. To use a mathematical analogy, we have knowledge and therefore certainty when we are aware of the presence of a variable; we also know its value. On the other hand, uncertainty comes from things we don't know. There are two types of things we don't know: we are aware of the presence of a variable but don't know its value or are unaware of the presence of a variable (and of course don't know its value, too). The presence of knowledge is Zero Order Ignorance (0OI), and the two types of uncertainty are First and Second Order Ignorance

(1OI and 2OI) [1]. Except under very special circumstances, when we begin a project there are many things we don't know. Some of these things we are aware of (1OI) and some we are not (2OI). It is this lack of knowledge, particularly the 2OI variety, that generates the uncertainty. Since software development is primarily a knowledge-acquisition activity, we spend most of our time discovering this knowledge. Simply put: over time our knowledge grows and our ignorance diminishes.

The ranges mapped out by the Cone of Uncertainty describe a probability function with respect to time (or budget, staffing, or other project attributes—see Figure 2). In early phases of the life cycle, the width of the Cone of Uncertainty at that point in time generates a rather flat probability distribution (see Figure 3). This means there is a wide range of answers that might generate a solution. If the function is extremely flat, the model will infer the project should take somewhere between a few weeks and a few decades. Since every project takes somewhere between a few weeks and a few decades this estimate might be accurate but is not useful in making a business decision.

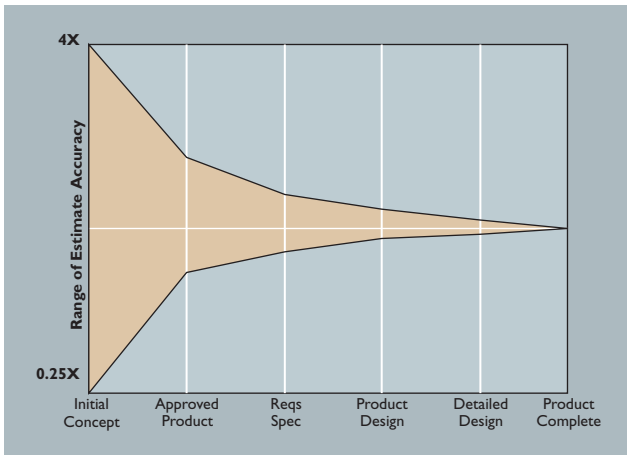


Figure 1. The Cone of Uncertainty (adapted from [3]).

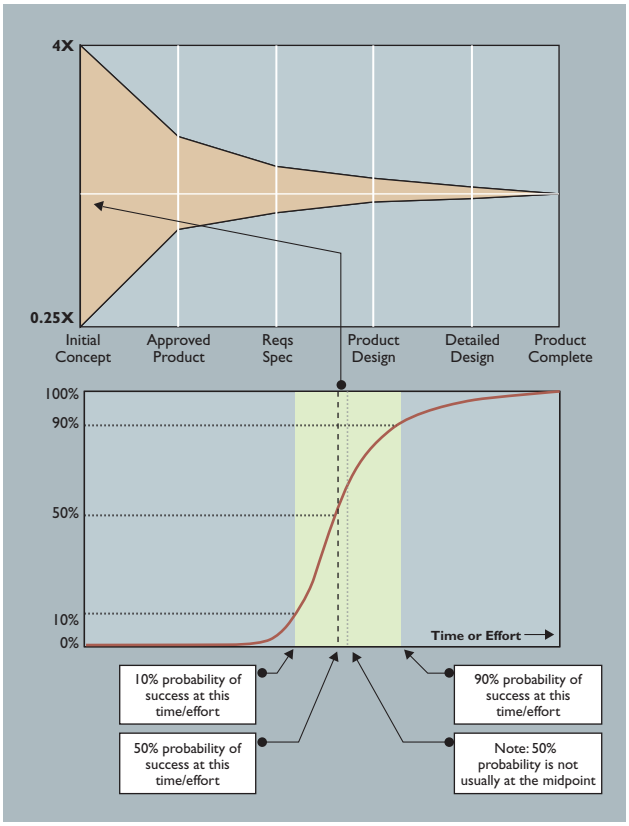


Figure 2. Probability distribution (adapted from Armour, P.G. Ten unmyths of project estimation. *Commun. ACM 45*, 11 (Nov. 2002)).

Hold to 10%

I recently spoke to a senior executive at a software consultancy. He was emphatic that when his project managers create an estimate, he will hold them to within 10% of the value they come up with. The Cone of Uncertainty would seem to fundamentally contradict the feasibility of that approach. The reason why an estimate cannot usually beat the Cone is that information about the project is imprecise at that point in time; the data is unavailable, unpredictable, inexact, or just plain wrong. No mathematical equation can have an output more precise than its input. In fact, this executive's hard-nosed approach to estimation will likely generate defensive behavior on the part of his project managers and estimators. Specifically, it may encourage them to try to overstate the problem, to "pad" the estimate in the hope of getting more resources. More resources of time, budget, and staff always means the project has a higher probability of achieving its goals within those resources. Management, however, is often allergic to estimate padding and

seeks to remove it. Removing the additional resources naturally has the effect of making the project riskier.

Manageable Risk?

The probability of success and its associated risk is a function of what is known and what is not known. Some risk may be manageable with a little effort, and we can usually attenuate risk if we are willing to expend a lot of effort. But some risk may not be manageable or predictable at all. The Cone of Uncertainty simply maps onto the knowledge/unknowledge content of the project over time.

It is interesting to note that the executive mentioned here does not really want an accurate estimate; what he wants is to have some assurance the project will be delivered within some constraint of budget, time, and staff. It might seem this is the same thing as an accurate estimate, but it's not. Perhaps this is where we should look for "accuracy"?

The Accurate Commitment

I recently completed an estimate of a large project for a client. It directly supported the estimate done by the project's program management office, but I calculated the probability of achieving the stated budget at 65%, which was just about where it should be. Since this probability was higher than expected, the project manager asked "Can I quote a lower price then?" The answer is, of course, yes—but at a higher level of risk. In fact, he could quote the price a lot lower, if he was also willing to take a very high risk of not actually achieving it. This is where accuracy is really measured.

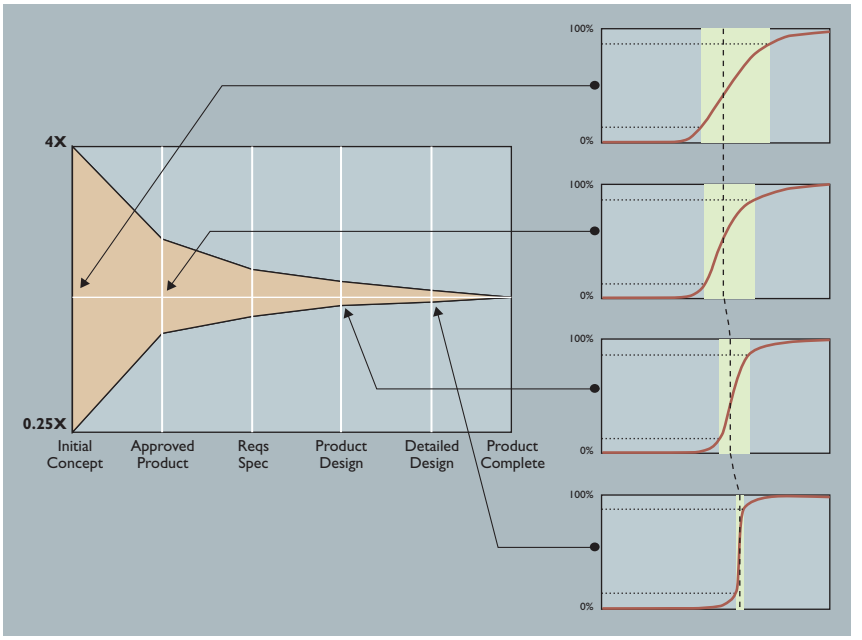


Figure 3. Probability over time.

We don't need an accurate estimate; we need an accurate *commitment*.

The commitment is the point along the estimate probability distribution curve where we promise the customer and assign resources. This is what we need to hit, at least most of the time. It is not a technical estimation activity at all but is a risk/return-based business activity. It is founded on the information obtained from the estimate, but is not the estimate. Using Figure 3 as an example, if we needed an accurate commitment in the earliest (Initial Concept) phase based on how the diagram shows the project actually worked out, we would have had to commit at around a 75% probability. From the figure, committing to the "expected" result at Initial Concept would have led to a significant overrun beyond that commitment, and the project would have "failed." We can consider the 50% (expected) result to represent the cost of the project and the 25% increment to the higher commitment level to represent the cost of the risk of the project.

The accuracy of a weather forecast is not whether it rains or not but whether it rains at the likelihood it was forecast to rain. Similarly, the accuracy of an estimate on a project is not whether the project achieves its goals but whether it correctly forecasts the probability of achieving its goals. In fact, I saw this recently, where a project had been committed at an estimated 20% of success. While

the project failed we could (and did) reasonably argue that the estimate was, in fact, accurate since it correctly forecast the failure; paradoxically, if the project had been successful we could consider the estimate to have been wrong.

The problem wasn't the estimate but the commitment. If we commit to a low probability of success on a project we are gambling with our budget, staff, and customer relations and that is often not a good thing.

Rein in the Commitment

If there is a 40% chance of rain and I decide to walk outside in my expensive suit without an umbrella and it rains on me and ruins my suit, it is not the fault of the forecast; it is the fault of my decision.

If we calculate the level of risk we are taking on a software project and choose to roll the dice with the odds stacked against us, it's not the fault of the dice. It is neither fair nor, well, accurate to blame a good estimate for a bad commitment. C

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Phillip G. Armour
(armour@corvusintl.com) is a senior consultant at Corvus International Inc., Deer Park, IL.

Coming Next Month in COMMUNICATIONS OF THE ACM

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Knowledge Management in Small and Medium-Sized Enterprises

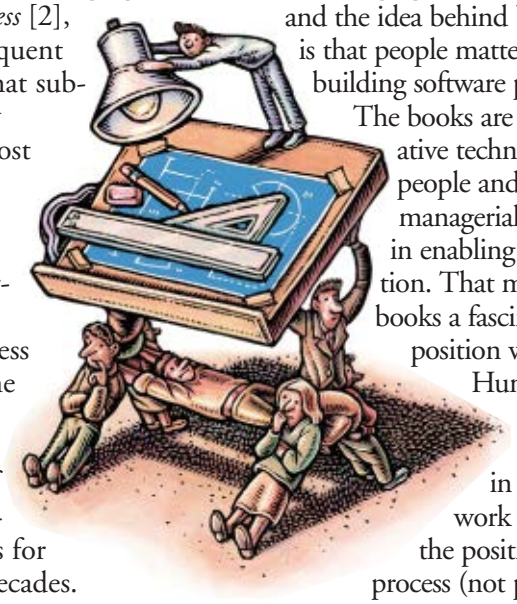
Demographic Changes in IS Research Productivity

"Most Wired Hospitals" Rate Patient Satisfaction

Managing for Innovation

People versus process? Watts Humphrey says it's people *and* process.

Watts Humphrey is best known for his work on software process at the Software Engineering Institute. His first book, *Managing the Software Process* [2], and his subsequent writings on that subject, are likely among the most significant works in the field of software engineering, and that work on process has been at the heart of most important discussions of software engineering topics for at least two decades.



Two years before his first process book, Humphrey wrote another book, *Managing for Innovation* [1]. This earlier book attracted almost no attention over the years, and yet in many ways it may be just as important as the better-known one. It was republished in 1997, as *Managing Technical People* [3] and—to the best of my knowledge—that version 2.0 book remains as little-noticed as the earlier one.

The subtitle of the innovation book is "Leading Technical People" (it is interesting that this subtitle graduated to the title of the version 2.0 *Managing Technical People*), and the idea behind both books is that people matter a lot in building software products.

The books are about innovative technical software people and the role of managerial leadership in enabling that innovation. That makes the books a fascinating juxtaposition with Humphrey's later process work, since in that later work he has taken the position that process (not people) is the key to software success.

But back to the earlier Humphrey book and its successor version 2.0. What is the relationship between innovation and creativity? Humphrey—quoting Theodore Levitt—puts it very succinctly: "Creativity is thinking up new things. Innovation is doing new things."

Humphrey goes on to add, "While innovation requires creativity, it also involves a great deal of hard work."

The book is about both creativity and innovation, although Humphrey is clearly more interested in the latter, because it is in the "doing"—the so-called "hard work"—that management's role comes to the fore.

What does Humphrey have to say about the intricate relationship between management and the creative technical person?

Regarding control, he reports findings from the literature that "managers who tightly control the way their people work generally get significantly less creativity than those with a looser and more informal style."

Regarding management technical knowledge, he reports other findings that "when the manager's ability was limited, innovation was highest when the group was given the greatest freedom."

"When the manager was highly skilled in administration, personnel, and technology," Humphrey went on, "the results were mixed; sometimes freedom helped, but sometimes it did not." Humphrey concludes with an old saying: "If you don't know what you're doing, then stay out of the way!"

Looking at the matter from a different point of view, Humphrey

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examines studies of successful and unsuccessful groups. "In the most innovative, the managers personally involved themselves in the work and maintained close technical contact with their people. For the least innovative, the managers were less active and more remote."

Is there a lesson to be drawn from this material? Perhaps it is "the most innovation comes when (a) the manager has technical skills and involves himself or herself in the group's work, while (b) maximizing the amount of freedom given his technical people."

Is technical creativity the most important factor in successful innovation? According to Humphrey and the studies he cites, the answer is no. In fact, the "persistent tendency of technical people to confine themselves to the laboratory and not to seek a detailed understanding of the user's needs" is one of the foremost reasons for research and development failure, he says.

What is the alternative to the laboratory-confined technologist? "Successful product development depends more on market astuteness than on technical competence," he says, quoting a University of Pennsylvania study. The most innovation, in fact (according to another study), comes "when the users were technically competent." That is, users, understanding the application problem to be solved, are more likely to produce innovation than computer technologists, who understand only the computing problem to be solved. Humphrey goes on to cite another study that found "75% of all innovations … came from market sources, but the highest percentage of technically driven innovations given by any single study was only 34%." That is, customer need, rather than technological progress, determines whether an innovation is likely to be successful or not. (Sounds familiar, doesn't it? It's a new variation on the old theme, "necessity is the mother of invention.")

An interesting aside in the book deals with the issue of how age affects creativity. Although there is a common belief that creativity and innovation peak at a fairly early age (it has been cited as being anywhere from 21 to 29), Humphrey says there is an increasing body of evidence that points the other way. In one study, the researchers found that performance peaked at an early age but declined very slightly thereafter. The precise point at which this peak occurred depended on the technical field; it was earlier in the more abstract fields of mathematics and theoretical physics and later in such pragmatic specialties as biology and geology. The initial peak fell in the mid-30s, but a later peak was also found in the mid- to late-50s. This double-peak phenomenon occurred in all the groups of engineers and scientists studied, and the dip between these two peaks was not very significant.

Humphrey summarizes with an encouraging thought (at least for older readers): "For creative people, the late 30s and early 40s is a highly stressful period. Once they pass this hurdle, however, many engineers and scientists will continue their creative work for many years…many of Thomas Edison's 1,100 inventions were produced late in his 84-year life."

From the point of view of managing for innovation, then, good leaders must know that any of their people, of any age, may contribute creativity and innovation.

These Humphrey books on the importance of people in the software process should be considered of equal significance with Humphrey's better-known process work. Both practitioners and academics will be enriched by reading either of these people-focused books—practitioners will see the books as an acknowledgment of their contribution to software process success, and academics will come to a better understanding of what constitutes successful practice. C

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Robert L. Glass (rlglass@acm.org) is the publisher/editor of the *Software Practitioner* newsletter and editor emeritus of Elsevier's *Journal of Systems and Software.* He is currently an honorary professor in the ARC Center for Complex Systems at Griffith University, Brisbane, Australia.

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Just Say 'A Class Defines a Data Type'

When teaching computer programming to novices, forget "objects early," "objects later," and "back to basics."

Ask a group of graduating seniors majoring in computer science to define a data type and chances are most of them would be unable to answer even loosely beyond simply providing examples. Then add the concepts of abstract data type and (Java) class, asking about the relationship between them. The same students would also be unlikely to find an answer in a CS1 textbook. Some textbooks might not even contain terms like data type, abstract data type, or type. Yet the study of data types is fundamentally important to learning programming with a typed programming language. Moreover, if novices do not learn data types the right way—consistent across different data types and programming paradigms—some would face insurmountable difficulty learning object-oriented programming, no matter when they learn it. Without a proper characterization of data type, the textbook, as well as the instructor, would be fundamentally challenged to present everything else effectively or even correctly, no matter which approach they took.

When associating the concept of data type and a computing language, a correct definition should be consistent with the following: A data type characterizes how a set of entities is internally represented and algorithmically manipulated. Learning computer programming progresses with the level of maturity commensurate with the learner's sophistication in understanding and using data types.

Novices typically have much more difficulty learning about abstract data types, or ADTs, than about other data types. A reason for this is the lack of adequate coverage early on about data types, their structures, and the roles they play in problem solving, thus making the learning of ADTs a disconnected experience. For example, when learning built-in primitive data types, novices might naively take operations (such as +) for granted. Later, they may encounter the same + applied to strings. However, they normally miss the implication of what they see in both cases—the same apparent operation defined and implemented differently in the respective data types, depending on how the underlying data is represented.

A class (as in an object-oriented programming language like Java) defines a data type. Yet this fact is typically not mentioned in CS1 textbooks. Lacking an accurate description of a data type, the best a textbook (or an instructor) can do is say something like: A class is a template, blueprint, or pattern of an object. These characterizations suggest how a class can be viewed, not what a class is, much less what a class can do, thus making it difficult to learn the true nature of a user-defined data type.

Having learned primitive data types and standalone methods when covering ADTs, novices typically experience a drastic change in the level of abstraction (an ADT is essentially a mathematical algebra) they were unprepared for while learning primitive data types. Unfortunately, this disconnected learning experience is interpreted as "getting a mindset in procedures" by some educators. It was in this context that the notion of "teaching objects-first" was born about a decade ago and is still a reasonably popular teaching strategy for a course for beginning programmers, despite the ongoing con-

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Why can't educators give their students a consistent view of a data type regardless of whether it is a primitive or user-defined?

troversy. To help with "teaching objects first," educators, notably the creators of the 3D storytelling programming software Alice and integrated programming environment BlueJ, have developed software for visualizing objects and teaching materials using visual objects (such as robots, graphics, and role-playing games). Do they work? The answer depends on who you ask. Educators must still address how novices transform their ability to manipulate visual objects into programming skills. However, the educational shortcomings attributed to poor understanding of ADTs may be rooted more deeply than not understanding what objects are and how they behave.

Textbooks have been written to support the objects-first or objects-early approach, though few of them reflect problem solving at its core. Here, I define some of the more apparent problems I have observed in recent Java texts (none cited in the references here):

Effective teaching methods. Novices learn about object instantiation and behavioral method calls from the start; they may even learn software engineering principles in chapter 1, an approach analogous to teaching babies to speak sentences when they are barely able to speak a word.

Class design. When trying to identify classes, "noun extraction" seems to be a straightforward process, as covered in some textbooks. However, abstract nouns can end up as the basis for defining data types, while a primitive data type may be all that's needed for what is otherwise a user-defined data type. Architectural data types are rarely implied by the nouns of a requirement description, and verbs may wind up defining operations of some unexpected data types. That is why identifying classes generally requires program analysis, a process that's still far from straightforward.

Consistent view. Primitive data types are value types, and user-defined types are reference types. So why can't educators give their students a consistent view of a data type regardless of whether it's primitive or user-defined? A primitive data type encapsulates data in binary format, represents data in an internal format (say, the two's complement, or the way a computer represents integers internally using 1s and 0s), and defines operations we often take for granted. Few programmers would care how + is implemented should integers not be represented by the two's complement. Thus, the level of abstraction, in which + is invoked, separates the relevant detail of "what" from the irrelevant detail of "how"—the essence of ADTs. (OO programming languages also address the "mechanical" differences through autowrapping and unwrapping features.)

Toy objects. Objects with "toy" behavior are often included in textbooks yet solve no practical problems. Assigning appropriate methods to an object is among the most difficult lessons a novice can learn. A program design often dictates whether an object should or should not have certain behaviors due to architectural, maintenance, or efficiency concerns. For example, the statements `student.isScholarshipEligible()` and `financialAidOffice.isScholarshipEligible(student)` may be interchangeable in an application, depending on the design; the question for educators is not whether novices should reach such a level of sophistication, but how they might get there. Toy object after toy object will almost never provide a viable path to this level.

Programming paradigms. "Objects early" means "object-orientation monopoly" in many textbooks. Studies of the practice of software engineering show that object orientation is not a dominant paradigm in real-world software development [1], so why should educators act like it is when teaching novices programming? In fact, viewing software as a service, developers have found a new role for procedural data abstraction in data-intensive and highly distributed business applications. Data handling is mostly proce-

dural in nature; for example, the object-data source control of the ASP.net framework works directly with standalone methods. How can educators introduce object orientation to novices so it is simply a means for problem solving, not a hammer looking for a nail.

A debate "Resolved: Objects Early Has Failed" at the 2005 Symposium of the ACM Special Interest Group on Computer Science Education drew a sizable crowd, and in 2007 a back-to-basics textbook [2] was published. Interestingly, this sequence of "structured programming, teaching objects early, then back to basics" reminds me of the "drills, reformed calculus with technology, back to fundamentals" cycle the mathematics teaching community has experienced since the late 1980s. The critics still believe that the movement to reform the teaching of calculus fails to educate students, considering the courses watered down. Students, they say, come out of introductory calculus courses with no idea how to solve complicated mathematical problems [4]. One can argue (many CS educators indeed do) that teaching "objects first" has compromised teaching algorithm skills. Going "back to basics" in teaching computer programming may avoid some of the problems teaching "objects first" has brought but would still not solve the problem of a difficult transition from procedures to objects that teaching "objects first" sought to address in the first place.

Learning computer programming essentially involves two things: computer algorithms and how data types are defined, designed, and used to solve problems. Meanwhile, novices need a paradigm shift away from solving problems with paper, pencil, and calculator toward solving them algorithmically with conditionals and loops; they also need a gradual introduction of data types with consistency in a problem-solving context. We need a teaching approach that would better capture the essence of learning problem solving through programming with (instead) both procedural and object-oriented problem-solving paradigms. One such approach might include the following content:

- The difference between solving problems with computer programs and with paper, pencil, and calculator;
- The role of data types in problem solving through programming;
- Variables and their roles in assignment statements and elementary programming activities;
- Primitive and library-defined data types, including how they are defined, represented, and used;
- Simple control structures, more roles for variables [3], and a first look at procedures or methods;
- Problem solving with user-defined data types introduced in a context of solving meaningful problems;
- Essential-yet-simple computing algorithms;
- More control structures;
- Array data types and more computing algorithms;
- More problem solving with user-defined types, standalone procedures, or both;
- Type inheritance and its role in problem solving; and
- Problem-solving case studies.

This is neither "objects-first" nor "objects-later" but serves as an invitation to better ideas in teaching novices, not just how to program but how to solve problems through programming. We clearly need another approach to teaching programming to novice students besides "objects first" and "back to basics." C

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Chenglie Hu (chu@cc.edu) is a professor of computer science at Carroll College, Waukesha, WI.

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Their technical papers, books, university courses, computing programs and hardware for the emerging computer/communications amalgam reflect the powers of their vision and their ability to inspire colleagues and students to drive the field forward. The members of the ACM are all participants in building the runways, launching pads and vehicles of the global information infrastructure.

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Nominations and endorsements must be submitted online by Sept. 9, 2008.

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By Dana Cuff, Mark Hansen, and Jerry Kang

Urban Sensing: Out of the Woods

Embedded networked sensing, having successfully shifted from the lab to the environment, is primed for a more contentious move to the city to where citizens will likely be the target of data collection. This transition will warrant careful study and touch on issues that go far beyond the scientific realm.

A fundamental shift is under way in pervasive computing. Within academic research, pervasive computing in the form of embedded networked sensing has leapt from the laboratory to the natural environment [7]. Simultaneously, in the domain of personal communication and corporate marketing, pervasive computing has entered the backpack, purse, and coat pocket in the form of mobile phones, laying the groundwork for Mark Weiser's vision of ubiquitous computing [12]. We characterize this contextual shift as "urban sensing," which augurs a fundamental transition from science and engineering into the realms of politics, aesthetics, interpretation, and motivation. More than a change in degree, this is a change in kind that warrants careful, transdisciplinary study.

In bucolic Lake Fulmor in the San Jacinto mountains, seven incongruous buoys dangle strings of thermistors to acquire time series of temperature at several different depths (see Figure 1). Suspended from each buoy, at half a meter below the surface, is a submersible fluorometer recording chlorophyll concentrations. A team of biologists and engineers from the University of Southern California oversees the system and collects sensor data wirelessly from shore; visualization tools help this group examine both the physical and biological dynamics in the lake. For a more complete picture of the local environment, data from the buoys is combined with wind speed and other microclimate measurements from a nearby weather tower at the James Reserve, a biological field station that is part of the University of California Natural Reserve System.

Figure 1. Sensors floating in Lake Fulmor.

A robotic sensing device is installed at the deep end of the lake, sponsored by UCLA's Center for Embedded Networked Sensing (CENS), an NSF Science and Technology Center (CCF-0120778). The robotic system consists of a cable that spans the lake at its widest point, oriented perpendicular to the line of buoys. A small shuttle rides along this cable carrying with it a sensor node that is dipped into the lake at regular intervals. The shuttle submerges the node and its cluster of sensors, taking measurements at several depths. The resulting data forms a grid, profiling temperature, chlorophyll concentration, and about a dozen other variables in the plane of the cable system. When paired with the static buoy data, a model can be formed that captures the important chemical, physical, and biological processes in the lake.

Nearby, buried wireless sensor nodes record soil temperature, moisture, and CO_2 concentration, and a robotic camera rides through an acrylic tube shooting pictures of roots and fungi. Still other devices monitor activity in nestboxes, where an image is collected every 15 minutes, then subjected to a series of processing algorithms that recognize whether the box is occupied as well as higher-level events like nest building, egg laying, and hatching. The use of imagers as biological sensors is a new research thread for CENS.

The rollout of these embedded networked sensors has coincided with other advances within the larger area of information technologies, and specifically the proliferation of geocoded data and the accompanying GIS platforms for its visualization. Services such as Google Earth have driven to nearly zero the cost of this visualization measured in terms of dollars, time-to-deploy, and technical sophistication required. So-called "mashups" with Google Maps provide anyone with a Web browser the ability to display data (sounds, images, video, statistics, and so on) in map layers. In combination with the embedded networked sensors, such systems have greatly reduced the technical barrier to visualize data in real space, to construct maps of layered information, and to analyze locational phenomena over time.

The move by CENS from the lab to the forest has been a radical leap forward, pushing the capabilities of sensors and robots, as well as offering rich new understandings of the forest itself. In the last five years, we have seen a shift in the emphasis of sensing research, with greater importance being placed on data, data processing, and mathematical and statistical models for environmental phenomena. While the move to the forest directly furthers CENS' mission to grow technology in the context of specific scientific questions, the forest was an ideal site for scientists to conduct a series of fast experiments that sidestep the thorny cultural problems of ubiquitous surveillance that have entered public debate. With James Reserve as today's reality, we can ask: What happens tomorrow, when pervasive computing comes out of the woods and goes urban?

The City: Sensing Goes Public

The James Reserve represents what might be called a *full centralization* model: sensors, the data they collect, and the ways in which the data is processed is subject to centralized control by the scientists who plan the sensor deployments. This model cannot, however, scale to the city. Even if the enormous funds were available, scientists lack the property

MAKING URBAN SENSE

A number of applications can be viewed online to get a snapshot of the state of urban sensing today. These range from provocative public art, to mapping mashups, to real-time traffic tracking. At present, the remote, spatial sensor networks developed within the sciences and the military share virtually no overlap with the "experience design" innovations coming from artists, though both families of experiments utilize similar strategies. These include geo-coded data collection, mobile and fixed sensors that are spatially distributed, sensing networked with processing and actuating capabilities, and time-sequenced data, to name a few. In general, these projects seek to make something previously invisible visible. Most work with the spatial distribution of information, but some take spatial behavior as their object of interest.

Representations of urban sensing data vary widely in terms of their sophistication, both in terms of clarity and aesthetics. While some operate in the physical environment itself, others interpret the data, translating it into maps.

The list here samples a range of interesting urban sensing experiments.

D-Tower. A public sculpture in the Netherlands city of Doetinchem that displays the emotions of residents based on their responses to Web surveys; www.d-toren.nl/site.

White Noise White Light. Meejin Yoon's installation of a responsive sound and light field at the Athens Olympics; www.mystudio.us.

Living City. Projects in which buildings' sensors monitor environmental conditions that the buildings can responsively adapt to or improve; www.thelivingcity.net.

Fade to Black. In various cities, Natalie Jerimijenko's upturned Webcams collect particulate matter on their lenses to literally show pollution; www.bureauit.org/ftb.

Feral Robotic Dog. Jerimijenko repurposes robotic toys into toxin-sniffing dogs deployed in packs to converge on detected hazardous waste; www.bureauit.org/feral.

The Great Backyard Bird Count. Maps the cumulative counts of birdwatchers from across the U.S. over a four-day period; www.birdsource.org/gbbc.

Did You Feel It? A USGS site that maps data from individuals about their experience of an earthquake; http://earthquake.usgs.gov/eqcenter/dyfi.php.

Moveable Type. For the *New York Times* headquarters, the lobby installation by Ben Rubin and Mark Hansen spatially displays a dynamic portrait of the day's news and news browsing; www.earstudio.com/projects/moveable_type.html.

Walk Score. A mashup that assesses any neighborhood for its "walkability," particularly for browsers determining where to buy or rent housing; www.walkscore.com.

Urban gaming, like PacManhattan or Minneapolis's Big Urban Game, are examples of an interactive, playful use of urban sensing; http://pacmanhattan.com/ http://design.umn.edu/go/project/TCDC03.2.BUG

[*murmur*]. Signs in the city give a phone number for anyone with a cell phone to listen to stories about that particular location. A good example is in Toronto http://murmurtoronto.ca.

Real Time Rome. A project by MIT's SENSEable City Lab that visually represents real-time information about Rome's urban dynamics; http://senseable.mit.edu/realtimerome/.

TrafficSense. Cellint provides real-time traffic monitoring using cellular-based detection; www.cellint.com/traffic_data/traffic_system.html.

For more general urban sensing, see the Geobloggers Web site, www.geobloggers.com/archives/, Google Maps Mania http://googlemapsmania.blogspot.com, and Google Maps Street View http://maps.google.com/help/maps/streetview/index.html.

—Dana Cuff

rights to instrument everywhere, and individuals enjoy privacy rights not granted to sparrows.

How then will pervasive computing ever manifest itself in the city? We believe it will be through the little device that 70% of U.S. citizens already carry: the cell phone. Although we think of cell phones as communication devices that we episodically and intentionally use, we should recognize they are also passive sensors that can silently collect, exchange, and process information all day long. Obviously, they are engineered to sense sound—our voices—but they also can sense images and movement through their built-in cameras. Still more interesting, they can sense location through GPS receivers or basic cell phone triangulation. In addition to sight, sound, and location, inside of 15 years, cheap sensors that detect other aspects of the environment like pollution, will be available as plug-ins. Although various factors such as infrastructural rollout and pricing plans will influence adoption rates, we are confident that within this 15-year period, in most urban centers around the world, processing, visualizing, and uploading sensor data—even large

Figure 2. Interactive D-Tower in the Netherlands. Photo: Henk Vlasblom

amounts of it—will be accessible to a large percentage of their populations.

If the vector of entry will be an individual's cell phone, we necessarily move away from the James Reserve's *full centralization* toward a model of *distributed citizen-sensing*, sometimes called *participatory sensing* [2, 3]. In this model, although some central authority maintains the basic terms and conditions of data collection as well as the centralized data repository, that authority employs local data collectors (people like us) who voluntarily and idiosyncratically record data. A good example of distributed citizen-sensing is the Great Backyard Bird Count. Still further along this spectrum, we could imagine a *fully decentralized* model, with no central authority beyond some actor providing basic storage and search. This approach is even more in line with the Web 2.0 ethos, which values unconstrained user participation.[1]

[1]See Tim O'Reilly's *What is Web 2.0: Design Patterns and Business Models for the Next Generation of Software.* O'Reilly Media, (Sept. 30, 2005); www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html.

Another model of decentralized sensing comes from architecture, when measurements and models are shared between buildings with control systems that allow one building to shade another or mitigate the so-called urban canyon effect (for examples of these models, see the sidebar "Making Urban Sense").

Although it is difficult to predict where precisely on this spectrum we will end up, urban sensing shifts focus and control away from the scientist at the center. We can anticipate new forms of science built from large-scale citizen-initiated data collection. Data will also be collected, then interpreted, in ad hoc ways by everyday citizens going about their daily lives. This suggests that urban sensing will go not only beyond scientists, but beyond science itself. Should we be worried?

Beyond Science

There are at least two concerns: bad data processing and the "observer effect." First, when amateurs collect data through cheap, unverified, uncalibrated sensors, the immediate fear is "junk data." This may be merely incidental as when cell phone images frame what the photographer wants to show, with no pretense about neutrality or comprehensiveness. Or it may be more purposeful when the data collector has no commitment to epistemic objectivity. For example, neighbors documenting traffic congestion will rarely record traffic-free periods. Further, when statistically unsophisticated individuals interpret data, the immediate fear is "garbage analysis." With many eyes watching a set of data, the opportunities for incorrect inference multiply.

Second, observation generally and surveillance specifically alters human behavior. For example, video cameras for traffic or security are explicitly intended to alter conduct. When data collection is situated "outside" the thing being studied, observation remains arguably neutral. But when data collection is embedded among the actors within a setting, as in participant observation, a cycle of interactivity is launched in which observation changes behavior that changes observation and so on.

These concerns are serious, but not insurmountable. Various forms of distributed accountability can make data collection more reliable. For instance, a user may tell the network that certain sensors should "agree" with her measurements in order to register as acceptable or valid. Given its ubiquity, the sensing network itself can provide the redundancy necessary to identify and interrogate faulty data. For example, if one cell phone reports that it is moving 75 mph on a freeway, whereas all adjacent phones moving in the same direction report 45 mph, we can be skeptical of

the outlier datum. Even in so-called bottom-up systems, guarantors of data quality exist. In some sense, this is how we have come to identify reliable sources on the Web, when search engines like Google return millions of possibly relevant sources of information. In addition, data sharing projects like ManyEyes at IBM offer a kind of "social data analysis," in which graphics are open to discussion; and through such interactions, inferences improve.

More important, we embrace the idea that urban sensing can and should go beyond science, unabashedly, into the realm of art and politics. In these arenas, data quality may not be what is most important. To make this discussion more concrete, consider, for example the D-Tower, created by Lars Spruybroek/NOX for the city of Doetinchem in the Netherlands (see Figure 2). The D-Tower is a 12-meter tall public sculpture activated by responses to a Web site that surveys the mood of the townspeople. If most of the Doetinchemers are feeling fearful, it glows yellow, but when they're in love, the beacon burns red. Here, we've added an entirely new dimension to urban sensing—an aesthetic one in which data (responses to the online mood survey) is subjected to a heuristic devised for purposes of pleasure, humor, curiosity, and to a lesser extent, scientific truth. Numerous cities, public institutions, and designers are collaborating on urban-sensing projects, creating dynamic events that engage the citizenry. By generating publicity, these sensing mechanisms spark action and interaction, rather than merely record it. Although standards of data quality and participation apply to political and artistic projects, we can hardly ask whether the citizens are truthfully feeling happy when we observe a purple D-Tower. But we can debate whether the tower is responsive to and provokes some community feeling.

The data commons and citizen-initiated sensing will provide answers, pose new questions, and open new opportunities for public discourse.

The Data Commons

In going beyond science, urban sensing has the potential to generate a "data commons." By this, we mean a data repository generated through decentralized collection, shared freely, and amenable to distributed sense-making not only for the pursuit of science but also advocacy, art, play, and politics. One might ask how the data commons differs from the Web we already have, and indeed, the same question might be asked of the blogosphere and its relationship to the Web. Specific technological choices (syndication, linking, commenting) provide the blogosphere with its unique character. The same can be said of the myriad Web 2.0 applications that elicit user-generated content. Whether we view these new developments as an outgrowth of the open source movement or of the success of a few participatory models (Wikipedia, YouTube), the applications on the Web today and the way data is structured and shared are fundamentally different than they were a decade ago. We think of the evolution of the data commons as an extension of this movement, offering a host of new applications, new data types, and data processing tools. As Natalie Jeremijenko contends, every sensor in the environment is a question. The data commons and citizen-initiated sensing will provide answers, pose new questions, and open new opportunities for public discourse.

The data commons resembles what we have previously called a public sphere [7]. In prior work, Kang and Cuff provided a minimalist definition of the public sphere with four principal attributes: the public sphere must be accessible to diverse members; provide opportunity for multiple uses; encourage some sort of (and not always political) exchange among participants (in the case of a data commons, this implies both the sharing and consumption of information); and be recognizable as such a space. Although these attributes were used to describe physical realms and social practices, they can also be usefully applied to the data commons.

We are enthusiastic about a flourishing data commons for the same reasons we care about a vibrant public sphere. In particular, we are skeptical that democratic commitments will continue to be manifested—if they ever were—through stylized practices

of voting, political contributions, and face-to-face participation in local town hall meetings. Instead, individuals are increasingly manifesting their civics and politics through engagement of a public sphere understood far more broadly. This includes, for instance, "political shopping," in which individuals use pervasive urban computing to inform their marketplace decisions to further non-marketplace values, such as environmentalism or fair trade. Indeed, in the modern globalized capitalist environment, individuals express their social and political values as much through consumption choices, like (Product) Red, as they do through voting.

But practices such as political shopping (or "political eating" or "political commuting") require access to the varied sorts of information that a sprawling data commons could best provide. Indeed, civic participation itself may be measured by our contributions to the data commons. Take, for instance, the use of YouTube in the recent Presidential debates or the activity recorded by VideoTheVote.org in the last round of nationwide elections. Other examples that foreshadow a process of deeper civic engagement include reviews of products, tagging of data, comments on blogs, uploading of photographs and other information when newsworthy events take place—whether natural disasters or armed invasions—and citizen sensors are there to capture the moment. Consider a recent development, the so-called "placeblog." These are sites that function somewhere between a local paper and a blog; they aspire to record the details of a particular place. Similar moves can be found in daylife.com and newassignment.net. Such initiatives are consistent with the spirit of participatory GIS, which explicitly enlists the community to make a case or to study some aspect of life locally.

Building a Data Commons

A data commons is valuable because it allows all of us to engage each other about what we newly "see" in the places and communities we inhabit. And we cannot take the building of the data commons for granted. Notwithstanding the buzz over Web 2.0 and sites like Flickr, it is presumptuous to think we will naturally and inevitably have a vibrant data commons, and the best possible one at that. What sort of data commons gets built depends on legal, policy, and technological (especially user interface) decisions we make now.

Property. Consider, for instance, the law of intellectual property. Copyright law only protects creative expressions; it does not protect the underlying data. Accordingly, one might be anxious that "data" will be underproduced because there will be no easy way to incentivize its collection and distribution. This fear misunderstands what drives our contributions to the data commons. Countless examples of cooperation, collaboration, and even play, especially mediated through the Internet, demonstrate that many substantial projects are not motivated by the prospect of significant financial remuneration (for example, Amazon's Mechanical Turk, weatherunderground.com, and the Google Image Labeler).

Instead of financial gain, one of the biggest motivators for citizen-sensors to share data may be *attribution*. Content providers tabulate hits and the number of blog links, while the USGS's "Did you feel it?," which asks citizen-sensors to record how strongly they felt earthquakes, allow data collectors to see how their data contributes to a larger whole. Such attribution can be designed without any expansion of intellectual property rights over data.

In fact, creating robust intellectual property rights over data risks a tragedy of the anticommons, a concept introduced by Michael Heller [5]. If too many property rights are created, the cost of coordinating permissions among multiple, fragmented property rights owners prevents otherwise interesting, useful, and dynamic engagement with the data. To provide an urban sensing example, imagine geocoded digital images uploaded to some photo-sharing site. If some 3D visualization mashup required IP clearances for each and every photograph, the transaction costs—even imagining efficient intermediaries—would be prohibitive.

Privacy. Because urban sensing collects information in environments inhabited by and directly connected to human beings, the data collected will often constitute personal information. Accordingly, urban sensing raises serious privacy concerns in a way that surveillance in the woods largely avoids. To be precise, by privacy, we mean *information privacy*: an individual's claim to control how personal data is collected, distributed, and processed [1, 3, 6, 10]. A patchwork of privacy laws already pertains to various aspects of urban sensing, especially when it takes place in private property not generally accessible to the public. The common law tort of invasion of privacy as well as statutory limitations on video and audio taping could prevent various forms of urban sensing—an obvious issue to consider. Two less obvious aspects of the privacy problem are worth mentioning: self-surveillance and network solutions.

We tend to think of privacy claims being stated by the target of observation, and infractions as generated by others, be they corporate, state, or individual. While the threats such agents could wage in a distributed network should not be discounted, there is

another type of incursion that is rarely debated. Because sensors will be carried on our bodies, in our automobiles, or sited on our real property, the persons about whom most information will be collected are ourselves. Persuading individuals to engage in such constant self-surveillance and then subsequently to share that data pose nontrivial hurdles entirely independent of the privacy claims raised by third parties. This is so even in the world of JennyCam and YouTube exhibitionism.

Whether we decide to engage in self-surveillance for the purposes of urban sensing depends in part on what the underlying computing technologies allow us to do. For example, if computer security is weak and information collected for personal use is vulnerable to third-party hacks, we will be less likely to collect that information in the first place. Similarly, if personal data cannot be easily scrubbed to become anonymous or pseudonymous or if it is difficult to control the granularity of data being released, people may be less likely to share that data publicly.

The network itself can develop services to help individuals negotiate their various privacy relationships [3, 11]. For example, two of the most extensively studied problems in traditional sensor networks are localization and time synchronization. The network knows (or will shortly know) precisely when and where data is published. While these two pieces of data are critical for scientific applications, they raise privacy concerns in urban settings. The network could, if properly designed, implement a kind of resolution control by verifying data up to whatever resolution that a user permits. The tighter the resolution, the more useful the data downstream; but this choice could be left up to the individual provider.

Of course, whenever we think about "choice," we must recognize not only the cognitive limitations in the exercise of such choice but also that privacy preferences depend heavily on the background culture. Privacy preferences are adaptive, as should be evident from a cursory analysis of the kinds of information disclosure deemed sensitive over time. Thus, today's exotic and disturbing data collection practices may appear banal 10 years hence. To the extent that privacy preferences are adaptive to the environment in this manner, we must be aware that today's policy choices will have long-term path-dependent effects.

Interface. Even if individuals are motivated to participate and the underlying legal regimes make it possible to do so, user interface is critical to both data collection and interpretation. For example, if collecting and uploading (known as sensor blogging or "slogging") local pollution data is too difficult or costly, people will simply avoid the hassle, or if searching for useful data is futile, the data commons will not grow.

Part of the success of blogs can be attributed to extremely simple tools for creating and publishing content. Perhaps more important than content creation, the simplicity of sharing this information is key, as are distribution mechanisms like RSS that allow people to register interest in content and (thanks to reblogging tools) republish selected portions. This pipeline model is not dissimilar from what we might expect from citizen-sensing. Easy data discovery, subscription, and republication will be crucial.

Far from a database query, it would be a reasonable outgrowth of existing technologies if the data commons were built from disparate sources of shared data (following simple publication mechanisms), informally organized (as with meta tags), open for discovery, visualization, and comparison, and subject to republication (modeling feed-forward). In part, discovery in the data commons might borrow from these existing services, relying on republication/aggregation/modeling as a kind of link between data sources (for example, if I generate an interesting graphic or fit a regression using your data, a link is automatically established) [4].

Today's exotic and disturbing data collection practices may appear banal 10 years hence. To the extent that privacy preferences are adaptive to the environment in this manner, we must be aware that today's policy choices will have long-term path-dependent effects.

LEGAL IMPLICATIONS OF URBAN SENSING

In addition to laws on property and privacy, questions of legal liability will influence how the data commons grow. Consider, for example, the potential liability of database intermediaries. Even in what we call a fully decentralized model of the data commons, it is highly likely that some database intermediaries will have to provide the basic platforms necessary for data search and storage. Current examples include Google, YouTube, and Facebook. The basic question is whether a firm such as Google should be held liable for the content it hosts.

This question has been carefully studied in the context of third-party copyright liability, but copyright does not attach to data. More relevant in this context is whether database intermediaries might be held liable under tort law, such as defamation. On this matter, unexpected legal reinforcements buttress the creation of a data commons by immunizing intermediaries.

Among federal laws, consider the significance of 47 U.S.C ß 230, which was passed as part of the Children's Decency Act (attempting to regulate Internet pornography), itself part of the 1996 Telecommunications Act. Under this provision, if some unrelated person uploads data onto a data commons platform provided by an intermediary, that intermediary may not be held liable for the damage that data might do. In practice, this means Google can provide database infrastructure for the general public to use with little concern about liability about what data is, in fact, uploaded.

Among state laws, consider the significance of anti-Strategic Litigation Against Public Participation (anti-SLAPP) statutes. These statutes, which are now common, were originally enacted to make sure that whistleblowers and political speech would not be chilled by aggressive litigation by large defendant corporations. But such a statute has been used to prevent overreaching by those who would stop data sharing within a data commons.

The celebrated case concerns Barbra Streisand, or more particularly, her home. The California Coastal Records Project (CCRP) has taken over 12,000 photographs of the California coast since 2002, in part to document incremental changes along the Pacific coastline. But some of those pictures included aerial shots of Streisand's house. Asserting a privacy violation, she sued. The CCRP responded with a special motion to dismiss under the California anti-SLAPP statute, and won that motion because Streisand did not have any colorable privacy claim. More important than the quick victory is the fact that the statute requires paying of attorneys' fees, thereby making it more difficult for wealthier parties to use meritless lawsuits as a chilling measure.

The point here is not to provide an exhaustive list of relevant legal regulations. Rather, it is to emphasize how legal protections designed for very different contexts may have surprising or unexpected consequences on the building of the data commons.

—Jerry Kang

The Fates

The mere existence of a data commons is not a panacea since it is essentially public infrastructure—a powerful resource that can be misused or underrealized. Here, we forecast potential fates of the data commons by drawing on Greek mythology.

Sirens. A mantra in the field of embedded network sensing is that it will "make the invisible visible." This has already taken place in scientifically controlled natural environments. It will soon take place within our cities, through decentralized processes, often without scientific goals or consequences. New sensing capabilities can make insidious urban qualities, such as buried toxic waste sites or ground water toxins, more visible to citizens. However, the new vision may be more like the Siren's song seducing us to make poor choices.

More information does not necessarily produce more rational (in the sense of instrumentally efficacious) decision making. Well-known cognitive biases might lead us to pay more attention to particular types of data than they rightly deserve. Consider, for example, the rough and ready risk calculation that individuals make in deciding where to live. If the data commons offer ready depictions of violent crime rates in the city, such information might persuade people to move to the distant suburbs in spite of the far greater mortality risk created through the increased highway driving. Relying on this highly salient, unidimensional "crime statistic" could produce a self-fulfilling prophecy that makes those areas with high crime rates grow more dangerous, while other areas get ever lower crime rates.

In response, we encourage data presentation practices that self-critically examine how individuals might easily misunderstand the data. And since none of us is entirely objective, we encourage what might be called "rights of reply." Just as blogs often provide spaces for comments, we envision data visualizations linking interpretations to counter the Sirens with their own melody.

Cyclops. In one version of the tale, the Cyclops is granted the power to see the future: again, the invisible suddenly becomes visible. Unfortunately, the

Cyclops is deeply saddened because the only future he is permitted to see is the circumstance of his inevitable death. As they say, when the gods want to punish you, they grant you your wish.

The tragedy of the Cyclops—that is, the impossibility of effecting change notwitstanding foreknowledge—might be visited upon us as part of the data commons. For example, it is possible that distributed environmental sensors could detail with alarming precision the nature and extent of our environmental poisoning. Those without financial or political means may be left with debilitating information about the nature of their demise without any practical ability to change their circumstance. Might there be some way out of this fate?

Without attempting any grand theory about how and when new information might catalyze change in political, social, and economic systems, we offer one novel idea: arbitrage our ignorance. This draws on the idea of a "veil of ignorance" offered by the widely read political philosopher John Rawls [8], who famously argued in favor of adopting principles of justice that would be agreed upon by persons in an ideal choice position (called the "original position"), which included deliberation behind a "veil of ignorance." This veil prevented persons from knowing what station of life they would find themselves in. If urban sensing lifts the veil by making the invisible visible, we must find ways to create some consensus before we learn the new information. After the information arrives, the predictable reaction is for the rich and powerful to respond to that information in self-serving ways. By precommitting to a particular principled response before the veil is lifted, we may be able to mobilize the collective resources necessary to avoid a tragedy of the Cyclops.

Conclusion

Embedded network sensing has made the leap from the laboratory to the natural environment through the careful design of professional scientists. It is now crossing into the urban context, but leaving behind the primacy of both scientists and science. The widespread use of cell phones, availability of GIS-related technologies, growth of Web 2.0, along with advances in sensor technologies have unleashed urban sensing. This new arena is fertile ground for participatory, collaborative efforts between citizens and scientists, artists, urbanists, and business people. As a form of public infrastructure, the data commons is essential for citizen participation in politics, civics, and aesthetics—as well as science. What we do today will influence what the data commons becomes tomorrow. And only through deliberative effort and political engagement can citizens navigate around Siren calls and the tragic Cyclops. C

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Dana Cuff (dcuff@aud.ucla.edu) is a professor of architecture and urban design at the University of California, Los Angeles; www.cityLAB.aud.ucla.edu.
Mark Hansen (cocteau@stat.ucla.edu) is an associate professor of statistics at the University of California, Los Angeles; www.stat.ucla.edu/~cocteau.
Jerry Kang (kang@law.ucla.edu) is a professor of law at the University of California, Los Angeles.

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MOBILE GAMING

BY JASON O.B. SOH AND BERNARD C.Y. TAN

Recent technological advances in mobile devices have produced powerful mobile phones and personal digital assistants that come with ever-greater computing power, storage capacity, and graphical and audio capabilities. Playing games on them continues to attract millions of subscribers/players worldwide. For example, mobile gaming was the highlight of the 2006 Electronic Entertainment Exposition in Los Angeles, with Nokia showcasing its Next-Gen Mobile Gaming Platform and a series of new game releases. Also, several speakers at the same show cited numbers showing that an increasing percentage of users of mobile devices use them to play games.

Tens of millions of users worldwide play games, as well as make phone calls, on their cell phones and other handheld devices.

A 2004 In-Stat/MDR study said that about 6.5% of U.S. mobile-device subscribers were "extremely interested" or "very interested" in purchasing mobile game services [9] and projected that by 2009, 78.6 million people in the U.S. would be playing mobile games; it also said downloads of mobile games will have increased tenfold compared to 2003. Zelos Group found that in the U.S. alone, mobile games could generate $1.5 billion annually in revenue by 2009. In Europe, a 2003 study by Frost & Sullivan reported that revenue from mobile games would rise from just under $0.8 billion in 2002 to $7 billion in 2006 [1]. In the Asia-Pacific region, IDC reported that the wireless gaming industry is growing 40% annually and expects it to reach $1.3 billion annually by 2008.

Demand for mobile games is fueled by three main factors:

- Increasing mobile device penetration rates in many countries, especially Finland, Japan, Korea, and Sweden; many users of mobile devices are potential consumers of mobile games;
- The ability of mobile devices to deliver quality video and audio continues to improve significantly, making such devices suitable for playing mobile games; and
- The improving ability of wireless networks to handle broadband transmission, allowing users of mobile devices to download larger and more compelling mobile games.

They represent both business opportunity and threat for wireless carriers, application developers, and content providers. Indeed, they are happening so quickly that industry observers believe they can alter the basis of competition in the computer gaming industry. Key players have expressed a desire to exploit it. For instance, mobile device manufacturer Nokia launched gaming communities to build awareness and use of mobile games. As a major game publisher in Japan with 2.5 million subscribers for its mobile game services, Sega hopes to achieve similar success in the U.S. In its 2004 study, In-Stat/MDR said that mobile gaming would continue to increase in importance as a contributor to telecom industry revenue. A 2002 research report from DFC Intelligence forecast that 114 million people worldwide would be playing online games by 2006, most in the form of mobile games [6]. While industry analysts would not dispute the significance of the trend toward mobile gaming, many questions remain. Here, we examine key technology factors behind the trend and analyze the opportunities for and threats to key players (and potential new entrants) in the computer gaming industry.

The mobile gaming technology platform typically comprises a network linking a server and numerous clients (mobile devices). Through the server, which stores and controls game services, game providers are able to publish and distribute mobile games for players to download on their mobile devices. Some such devices may be gaming enabled (such as the Nokia N series). When mobile gaming users connect to the server, they are able to join multiplayer games, download new games, and view their scores. In online-game-play mode, players access the server to play mobile games with other players. In offline-game-play mode, players use Bluetooth-enabled mobile devices to form local area networks with other players (within a distance of about 10 meters) to play mobile games. Recent advances in wireless technology (in terms of speed and bandwidth) provide practically instantaneous data transfer, thereby enabling millions of people to play mobile games on the go (see Table 1).

Platform	Characteristics	Implications for Mobile Gaming
3G	Broadband, packet-based transmission of text, voice, video, and multimedia Data rates up to 2Mbps	Quality graphics and sound, enhancing gaming experience Bigger games downloaded in less time
4G	Interactive multimedia services with greater bandwidth, digital elements, global mobility, service portability, and network security Data rates up to 100Mbps	High-quality multimedia and 3D games with greater speed and efficiency Bigger games downloaded in less time More players "Global" multiplayer gaming
GPRS	"Always-on," higher-capacity data services (such as email, Internet browsing, multimedia messages, visual communication, and location-based services) Data rates up to 171kbps	Mobile games played "on the move" Colorful images Multiplayer games (such as Nokia's Pathway to Glory)
Bluetooth	Short-range wireless networks within 10 metres inexpensive and easy to connect Data rates up to 2.1Mbps	Local-area multiplayer games (such as N-Gage by Nokia and Zodiac by Tapwave)

Table 1. Wireless communication platforms for mobile games.

To support the explosive growth in the mobile gaming market, technology platforms are being created for the development of the games. Sun Microsystems' Java 2 Platform Micro Edition, or J2ME, and Qualcomm's Binary Runtime Environment for Wireless, or BREW, are the most prominent technology platforms used in the industry. Each offers an enhanced user interface, improved application usabil-

ity on small screens, and the ability to create games that can be run offline, eliminating the need for a constant network connection. Other promising technology platforms include Mophun (from Synergenix Interactive), ExEn (an execution engine from In-Fusio), and XNA (from Microsoft) (see Table 2).

The convergence of technology platforms is an opportunity for mobile-game content developers to target a worldwide market. They can develop mobile games for common platforms (such as J2ME and BREW). They can also quickly adapt existing mobile games for the common platforms. Given such benefits, different mobile-game content developers are likely to create mobile games that are compatible (based on the common platforms).

Platform	Characteristics	Devices
J2ME (Java-based)	Enables Java-based games to be played on mobile phones and PDAs Allows mobile device makers, wireless carriers, and enterprises to quickly develop, install, and run new games on wireless networks Widely accepted standard that works with multiple platforms Improves graphic and multimedia capabilities to suit mobile devices	Nokia Series 40 and 60 devices, N-Gage, Motorola T720
BREW (C-based)	Optimizes memory allocation, making it suitable for mobile devices with limited resources Supports game operators with such capabilities as secure over-the-air distribution of applications, billing and payment, and service monitoring and support Allows games to be played more quickly because it runs on C rather than Java	Motorola T720, Samsung A530, Samsung A610
Mophun (C-based)	Enables rich gaming experience with advanced 3D graphics, enhanced audio, and multiplayer capabilities	Sony Ericsson, Motorola, N-Gage
ExEn (Java-based)	Provides good graphical capabilities and fast processing speeds Enables additional game-development capabilities (such as sprite zooming, parallax scrolling, ray casting, and rotations)	Philips, Alcatel, Mitsubishi, Panasonic

Table 2. Technology platforms for development of mobile games.

Major producers of mobile devices aggressively try to alleviate the related technology limitations. For instance, the Nokia N81 handset (released in 2007) comprises a 16.7 million-color screen with integrated stereo speakers and full support for Java ME gaming applications. It can also switch effortlessly between portrait and landscape modes for playing games. Faster processors are also being used to enhance mobile devices for playing games. For instance, the Nvidia GoForce 3D (the world's first 3D wireless media processor, introduced in 2004) offers a level of processing not previously possible on mobile phones, PDAs, or other mobile devices. Mobile game developers are thus able to harness this powerful technology to create rich, dynamic, lifelike worlds and characters. Another example is the Imageon 3200 chip (from ATI) that allows higher-quality graphics and video to be displayed on standard PDA displays, thus boosting the quality of the gaming experience.

Research by Informa Media Group suggests that by 2010, mobile gaming will overtake both console and personal computer gaming in terms of market value. As new entrants challenge incumbents for this growing slice of the gaming industry pie, there is likely to be fierce competition by "content aggregators, publishers, handset manufacturers, resellers, and network operators" [3]. Key players in the gaming industry must position themselves to be able to exploit the new opportunities that are likely to follow.

The development and marketing costs for a console or personal computer game may run in the millions of dollars. In comparison, such costs for a mobile game are typically $100,000 to $200,000 (2006 estimates); for details, see www.aniway.com/flash_lite_for_mobile_game_developers/?p=35. Moreover, development kits for mobile games are widely available from phone manufacturers, including Nokia, helping mobile-game content developers create content for their phones. The low entry barriers for mobile games have helped spawn a proliferation of small mobile-game content developers.

A challenge confronting these developers, which typically lack strong marketing and distribution networks, is getting their products to consumers. Two possible solutions are:

Partners. Content developers can enlist mobile device manufacturers and network operators to distribute their products; for example, in 2004 Jamdat Mobile signed a series of agreements with network operators to make its products available to 880 million mobile device users worldwide. In Singapore, Gameloft (an emerging mobile-game-content developer) signed agreements with three major network operators—SingTel, Starhub, and M1—to distribute its products; and

Mergers and acquisitions. Content developers can enhance their long-term prospects through mergers or acquisitions. A larger mobile-game-content developer is more likely to survive than its numerous small mobile-game-content-developer counterparts. An example is Mforma, which went on an aggressive acquisition spree 2001–2004 [4].

Mobile-game content developers can also focus on women, a still often-neglected consumer segment seg-

ment of the gaming industry. Men generally prefer sports, shooter, and other action-game genres. Women are more likely to play puzzle and role-playing games. The focus of the gaming industry has historically been male players. But now mobile games are being developed to appeal to both genders. For example, The Sims is a runaway success in terms of revenue among both men and women. The trend seems sustainable because women tend to spend more on services related to mobile devices than do men. An article [2] highlighted the significant growth in the number of women worldwide eager to play and willing to pay for mobile games. Mobile-game-content developers can exploit such opportunities by developing mobile games specifically for women.

Key players in the gaming industry must position themselves to be able to exploit the new opportunities that are likely to follow.

As of January 2008, the use of 3G services is still much less than anticipated by industry analysts, mainly due to the prohibitive cost of 3G licenses and potential 3G implementation problems. Likewise, multimedia messaging has not taken off as predicted. Therefore, the current strategy of network operators is to try to derive more revenue from nonvoice services (such as downloading ring tones and pictures). Network operators increasingly look to sell services for downloading mobile games. Unlike other players in the industry, this should not be such a problem for network operators since the downloading of mobile games is like other nonvoice services.

The network operator Vodafone took such an initiative in 2002, launching the Vodafone Live! suite of services to integrate services like picture-sending, Java games, mobile Internet, and ring tones into a coherent package accessible over the general packet radio service network. In doing so, Vodafone was able to capture a good slice of the fast-growing mobile-gaming market. The strategy of integrating services is also being practiced by the Japanese network operator NTT DoCoMo through its highly successful i-mode services. Network operators are generally not strong in content creation, so a collaborative strategy would be useful. As an example, T-Mobile (a network operator) and Sony Pictures (a content creator) collaborated in 2002 to create "film-themed games for T-Mobile's wireless subscribers" [8]. Such a strategy builds on interest created by movies while encouraging nongamers to try out mobile games.

Another potentially lucrative business that network operators may also be able to exploit is massively multiplayer online games (MMOG). Unlike mobile games sold as a product that generates one-time revenue, MMOGs can provide network operators with an ongoing subscription-based revenue stream. As MMOG players subscribe in order to play with thousands of other players worldwide, they provide a self-generating revenue stream for network operators in the form of monthly subscription charges and data-transfer fees. Thus, network operators can link up with MMOG developers to create and market such games while providing potentially lucrative network support. A successful example is Botfighters, a mock combat game in which players use their cell phones to locate and "kill" opponent robots (released in 2000 by Swedish mobile-game developer It's Alive). This MMOG (which has since undergone numerous revisions) is played by tens of thousands of gamers in Finland, Ireland, Russia, and Sweden. In 2004 the game generated more than one million short messages per week in Moscow alone.

Manufacturers of mobile phones regularly introduce new models in a bid to attract new customers or get existing customers to upgrade their handsets and hasten the replacement cycle, as well as renew their contracts with their existing service providers. One way to do this is to exploit the growing interest in mobile gaming. For instance, in 2002, Nokia introduced the N-Gage (which has since undergone several improvements), combining the features of a mobile phone, an MP3 player, and a mobile gaming device. The N-Gage continues to be positioned as a direct competitor to the dominant mobile gaming devices—Nintendo's GameBoy Advance and Sony's PSP. Some PDA manufacturers have adopted a similar strategy. For example, Tapwave's Zodiac (released in 2004 in Asian markets) has received positive reviews as a PDA/mobile gaming device hybrid. In 2003, Sprint PCS released its Game Pad controller, which works with the Samsung A600 cell phone (introduced in 2003) to add console-like control to mobile games. The Sony Ericsson P800 combines a PDA and mobile-game device [5].

These innovations have generated profits over the past five years, despite the millions of dollars Nin-

tendo has generated in sales of handheld gaming devices, including the Wii video game console (introduced in 2006). However, as new entrants, mobile-device manufacturers may indeed face formidable challenges from incumbents as they try to capture market share. Nevertheless, as they enhance the gaming capabilities of their products, mobile-game-content developers can create more vivid and faster-paced games to entice mobile-phone subscribers to play mobile games.

Console manufacturers have traditionally provided the platforms for computer games. But with the rising tide of mobile gaming, console manufacturers would face tough competition from new entrants (such as mobile device manufacturers). Mobile devices in the near future should be expected to have better processing power, enhanced 3D graphics performance, and better audio capabilities. Meanwhile, Intel and Hitachi have developed specialized microchips for mobile phones to improve the quality of mobile gaming. In addition, improved network bandwidth and storage capacity have begun to put mobile devices on par with consoles. Indeed, the very existence of console manufacturers is threatened by such devices.

It is thus essential that console manufacturers improve their product appeal by combining gaming and general electronics functions. An example is the Sony PlayStation 3, with high-definition DVD and HDD recording capabilities, a product positioned as an integrated entertainment system, transcending the idea of mobile gaming. Microsoft's Xbox platform has also followed this trend by incorporating Internet, video, and photo-editing functions into the latest Xbox 360 console. Console manufacturers should also view backward compatibility as an important feature in future console development, protecting gamers' investment in earlier games while giving them access to the latest ones. Indeed, the success of Sony's dominant PlayStation 2 was due largely to its ability to allow gamers to play games made for its predecessor, the original PlayStation.

Traditional game-content developers have provided games for arcades and personal computers since the 1970s. Games now considered classics include Pac-Man, Donkey Kong, and FIFA Football. These developers have positioned themselves to create versions of their existing games for the emerging mobile-gaming context, thereby allowing gamers to play the classics anytime anywhere. For instance, Electronic Arts (an established game developer with much success in both console and personal computer games) has ramped up its effort to extend the highly popular FIFA Football and Tiger Woods Golf games to mobile gaming platforms [7].

Due to a lack of diversity, hardware inflexibility, and immobility, arcade games have experienced a steady decline in recent years. The emergence of mobile games further threatens this business. Hence, arcade-game-content developers must focus on games that cannot be played in a mobile-gaming context. They must design and develop new games with unique characteristics (such as those that involve body movement). Through props (such as motorcycles, dance pads, race cars, and musical instruments), these developers have managed to create several arcade games (such as Initial D Arcade Stage 4, released in 2007) that offer a more realistic experience (that cannot be replicated in a mobile gaming context). They are also exploring the possibility of incorporating network capabilities into arcade games by enabling players to engage in Web-based interactive arcade gaming.

As mobile devices become an indispensable component of everyday life, the market for mobile gaming is likely to continue to increase well into the future. Incumbents in the computer gaming industry must adapt to remain viable. New entrants to the industry can exploit the many new opportunities that are still emerging. C

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Jason O.B. Soh (jason.soh@accenture.com) is an SAP consultant in Accenture, Singapore.

Bernard C.Y. Tan (btan@comp.nus.edu.sg) is a professor and head of the Department of Information Systems at the National University of Singapore.

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By Liping Zhao

PATTERNS, SYMMETRY, *and* SYMMETRY BREAKING

Explaining software patterns by breaking the symmetry created by programming languages.

Software design patterns capture tried and successful design solutions [6]. Among different views on design patterns is that they are created to compensate for the design shortfalls in programming languages [5]—that is, design patterns are needed when programming languages cannot do the job in a straightforward way. Based on this view, Coplien and Zhao [5] postulate that there is a causal relationship between language features and design patterns and that relationship is couched in a more fundamental relationship between symmetries and broken symmetries. This article builds on that postulation and provides a further understanding and fresh articulation of patterns, symmetries, and broken symmetries.

ILLUSTRATION BY PEP MONTSERRAT

Most people have an intuitive understanding of symmetry, which often means a well-proportioned, well-balanced image, such as the appearance of the human body. In mathematics, symmetry is an operation (for example, a reflection) that manipulates the image (the human body in this example) rather than the image itself [10]. More accurately, symmetry is a geometric transformation under which the form of the image remains unchanged [10]. For example, reflection is a symmetry transformation under which the human body remains the same. Other symmetry transformations are rotation and translation. Hence a perfect starfish looks the same under five rotations (see Figure 1a), five reflections (see Figure 1b), and any number of translations—shifting along a straight line; a round ball remains the same under any number of rotations and translations. Objects like these, which remain unchanged upon reflection, rotation, or translation, are said to be symmetric or to exhibit symmetry.

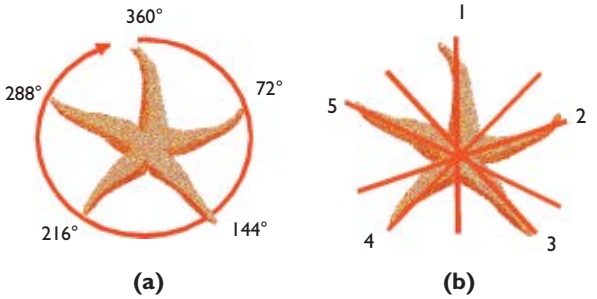


Figure 1. (a) The perfect starfish has a 5-fold rotational symmetry, about the axis through the center by 72°, 144°, 216°, 288°, and 360°; (b) 5-fold reflection symmetry, one for each arm.

There is a close relationship between geometric symmetry and the concept of invariance [12]. Symmetric objects are also said to be invariant, because their geometric features are preserved (unchanged) under symmetry transformations. Almost every conservation law in physics stems from fundamental symmetry in nature or from some basic principle of invariance. For example, the energy conservation law is based on the principle that the total energy, including that bound up as mass, must stay constant after a physical interaction. Hence, a physical interaction is a symmetry operation on the energy, which leaves the amount of energy unchanged.

Symmetry is closely related to isomorphism. From the viewpoint of abstract algebra, a symmetric system is isomorphic with itself; or, phrased differently, a symmetry operation is an isomorphism between two identical configurations of the system. For example, the starfish exhibits pentamerism and is isomorphic with respect to five rotations (see Figure 1a) and five reflections (see Figure 1b); each of these 10 symmetry operations is an isomorphism between two identical configurations of the starfish. Thus, isomorphism requires that two symmetric systems are not only apparently the same but also are exactly the same. Many programming features can be explained using symmetry either in its general concept of invariance or in its specific form of geometric transformation [5].

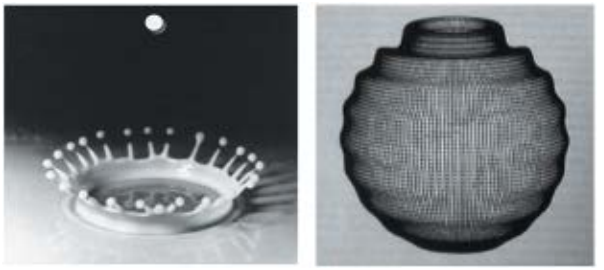
Symmetry Breaking

In physics, symmetry breaking happens when a force disturbs a symmetric system and causes it to break its symmetry to maintain its stability. This phenomenon has been explained in great detail by Stewart and Golubitsky [10] with abundant examples. One example is a splash of a milk drop. When a drop of milk hits the surface of a bowl, its spherical symmetry is broken into a crown (see Figure 2a). Under ideal conditions, a bilaterally symmetric aircraft should fly straight; in reality, however, the aircraft flies in a slightly zigzag way, because the flow of air past the aircraft is not bilaterally symmetric and the aircraft must break its symmetry to maintain its stability. Symmetry breaking is an important concept in many scientific fields. For example, the embryo development in biology and the electroweak interaction in physics are explained as a process of symmetry breaking [10].

Yet symmetry breaking does not mean a total loss of symmetry, only a partial loss. Before the milk drop hits the surface of a bowl it is invariant under all rotations; when hitting the surface, the milk drop breaks into a crown, which is invariant to only some rotations. If a ping-pong ball is compressed with a uniform radial force, it will buckle. Buckling will knock out some, but not all, of its rotational symmetries (see Figure 2b), because it will react to the force to rearrange itself to preserve as many of symmetries as possible to maintain its stability. Therefore, symmetry breaking is relative to symmetry: If the initial system is invariant to symmetry X, then after symmetry breaking, the resulting system is invariant to symmetry Y, such that Y is smaller than X.

Symmetry breaking has been recognized as a fundamental process of pattern formation [10]. If the force on the ping-pong ball is uniform, buckling will produce a symmetric pattern of identical dents on the surface of the ball. Thus, the pattern on the surface of

the ball arises from breaking the perfect symmetry on the ball. Stewart and Golubitsky [10] relate this phenomenon to the human perceptual quality that the human mind perceives too much symmetry as a bland uniformity rather than a striking pattern. Mathematically, as they explain, a uniform, featureless plane has a vast amount of symmetry; but people do not look at a wall painted in a single color and enthuse over its wonderful patterns. Similarly, a pond has a great amount of symmetry on its surface, but we are intrigued by the less symmetric pattern manifested in circular ripples on the pond. Patterns therefore arise from the contrast, the imperfection against the perfection, such as clouds against the blue sky, ripples on a fish pond, Chinese paper cutting, and the blot of ink on a paper. In all these examples, symmetry provides a norm—a backdrop—against which patterns arise.



(a) (b)

Figure 2. Symmetry breaking: (a) a splash of milk drop has lost its spherical symmetries to become a crown; (b) a buckled sphere has lost some of its rotational symmetries (from D'Arcy Thompson, *On Growth and Form*, Cambridge University Press, 1972).

Alexander, whose work on architectural patterns is a major influence on software patterns, has said that his understanding of patterns is closely related to the idea of symmetry breaking [2]. In [5], it is shown that software patterns can be explained as a result of breaking the symmetry created by programming languages.

Symmetry Created by Object-Oriented Language Features

Traditional OO design suggests that OO programs should be built from many small objects, like Lego bricks. This view has been challenged in [9], which reported there is no evidence of a typical size of objects (Lego bricks) to OO programs, and instead, OO programs are built from objects of variable size that exhibit scale-free, fractal geometry. The fractal geometry of OO programs may have important implications for debugging and garbage collection, according to [9], as the number of outgoing references of objects can be estimated using a power law; it may also help the designers to predict the number of objects and their relative sizes required in an OO program. Perhaps more important, this new revelation of OO program structure has reaffirmed the idea that software design, like architectural design, is essentially geometric.

This article takes a step further by positing that the fractal geometry of OO programs is full of symmetries, because OO programming languages, especially class-based languages, such as C++, Eiffel, and Java, have a great desire for symmetry enforced by their type systems. Since each type enforces some invariance to its instances, type systems are inherently symmetric. More generally, symmetries in programming languages are introduced by language designers in the name of design consistency, as expressed by Meyer [8]: "Throughout the design of a class library … we must constantly ask ourselves: 'How do I make my next design decision compatible with the previous ones?' 'How do I take my next design decision so that it will be easy—or at least possible—to make future ones compatible with it?'"

According to Meyer [8], the concern for symmetry is a special case of the concern for consistency. This article, however, views symmetry as a more fundamental design concept than consistency and that the concern for consistency is but a special case of the concern for symmetry. Symmetry reigns in language design. Class-based languages, for example, exhibit class symmetry, behavior symmetry, template symmetry, and method symmetry. This article explores and reveals these symmetries.

Class symmetry is associated with classes. Although it is clear the class concept is central to class-based languages, it is not always clear why the class concept is so important. According to Stroustrup [11], the importance of classes lies in their organizational power, rather than their computational power. He says: "C with classes was explicitly designed to allow better organization of programs; 'computation' was considered a problem solved by C [11]." A class specifies how a type of object can be constructed. Each type of object is invariant under its constructors because all the objects of the same type have the same configuration under their constructors. Objects of the same class can be said to be symmetric to each other because they belong to the same type. Classes can be viewed as a classification tool that classifies objects according to type invariants or type symmetries.

The Eiffel programming language imposes more class symmetries than other class-based languages, to the extent that Eiffel classes are too rigid. Every object of an Eiffel class is an invariant with respect to a set of assertions [8]. Eiffel has a strong connection to abstract data types, such that not only every object of

a class is symmetric to its type, but also every class is intended to be isomorphic to the type.

Behavior symmetry is linked to subtyping relation on object types [1]. An object type with more methods is said to be a subtype of the one with fewer methods. Subtyping is governed by the subsumption rule [1], which states that if b is an object of type B and B is a subtype of type A, b is also an object of type A. A practical use of this rule is known as the Liskov Substitution Principle (LSP) [7], stated as follows: "If for each object o1 of type S there is an object o2 of type T such that for all programs P defined in terms of T, the behavior of P is unchanged when o1 is substituted for o2, then S is a subtype of T." The importance of the LSP is that it places a behavioral constraint on subtypes and ensures a subtype object can always be used safely instead of a supertype object. Types that conform to a subtyping relation form a type family or type hierarchy. Such a type hierarchy is homogeneous because all the types in the hierarchy are of the same kind, a classic view of the "is a kind of" (IS-A) relationship.

Such a type hierarchy also has two important consequences. First, its objects have behavior symmetry because they behave exactly the same from an external observer's viewpoint and can be substituted one for another in terms of the LSP. As long as the LSP is not broken, the type hierarchy will be type-safe. Second, its objects have a polymorphic type because they can be viewed as belonging to many types of the type family. It is worth noting that objects that have class symmetry also have behavior symmetry because they behave exactly the same, but the reverse applies only to the objects belonging to the same type.

Template symmetry is associated with class templates in C++. A class template or generic type specifies how individual classes can be constructed much like the way a class specifies how individual objects can be constructed. Class templates are also designed for better organization of programs. Classes and class templates provide two orthogonal organizations of programs, such that classes organize objects into types, whereas class templates organize types into generic types. Class templates can be viewed as higher-level or meta-level type constructors. They are similar to meta-schemas in relational databases. All the types generated from the same class template have the same configuration and are therefore symmetric.

Class, behavior, and template symmetry can be generally referred to as substitution symmetry, as objects can be substituted one for another under class and behavior symmetry whereas types can be substituted one for another under template symmetry.

Method symmetry exists in many forms. In the first form, method symmetry is related to subclass methods. As a direct consequence of the subsumption rule, the sound typing rule for method overriding requires that the types of arguments of methods should vary contravariantly from classes to subclasses, and the types of results of methods should vary covariantly [1]. Another form of method symmetry is operator overloading. In C++, arithmetic operators are overloaded in classes to allow objects to behave as if they were primitive data values and to be expressed as the symmetry of left and right operands. Deeper than expressing this reflection symmetry, overloaded operators create symmetry of familiarity between built-in data types and user-defined types. Experienced programmers know the importance of method symmetry and have introduced many ad hoc symmetries, including complementary method pairs. For example, where practical, a creation method may match a disposal method; a getter and a setter; and a producer and a consumer. In Eiffel, every class method is an invariant against its pre/post conditions.

Symmetry Breaking Produces Patterns

Symmetry plays a major role in design for its aesthetic and functional value. One function of symmetry is its predictability: Symmetry shows us what to expect. In OO programs, class symmetry helps the compiler predict the behavior of objects, and method symmetry helps predict the behavior of methods. Another function of symmetry is imposing design consistency, as described previously. Yet perfect symmetry is austere in the extreme. In the visual world, our eyes often find a richer aesthetic content on partly symmetric reality. In biology and physics, the imperfections and irregularities in the arrangement of cells are more interesting because they pose deeper questions to scientists.

In program design, too much symmetry can lead to inflexible and rigid programs. Language designers have long recognized this problem and have introduced language features to break the rigid design. For example, abstract classes and interface features are designed to break class symmetry into interface and implementation symmetry. When language features are inadequate for breaking symmetry, software designers will invent their own gadgets to do the job. Over the years, some of these gadgets have survived and become what is now collectively called design patterns.

Design patterns thus viewed, have therefore arisen from breaking symmetry in OO programs. Although

WHILE DESIGN PATTERNS BREAK SYMMETRIES ENFORCED BY ORIGINAL LANGUAGE FEATURES, THEY CREATE THEIR OWN LOCAL SYMMETRIES, AND IN SO DOING, THEY ADD EXTRA FEATURES ON TOP OF LANGUAGES.

they are now used as solutions for breaking symmetry, they were actually the structure configurations left by symmetry breaking. Here, some popular class-based OO design patterns as in [6] are used as examples to illustrate how they break class, behavior, and method symmetry (for a formal definition of pattern, see [5]).

Class symmetry can be broken in many ways. A straightforward class symmetry breaking is using the abstract class or interface feature. When a language has no interface feature, such as C++, patterns, like Handle/Body and Handle/Body Hierarchy [4] (or Bridge [6]), can be used to break class symmetry. Class symmetry breaking plays a major role in the formation of the design patterns presented in [6], as many of those patterns stem from the idea of breaking class symmetry. For example, all the Creational Patterns are based on the idea of separating the object-construction process from the construction interface.

Why is the separation of a class into an interface and an implementation breaking class symmetry? It is because a class is broken into two. The original class symmetry is now split between the interface (where type invariants are found) and the implementation class (where implementation invariants are found). Since there can be more than one implementation class behind an interface, an interface can represent many sets of objects, each of which is symmetric to a specific implementation class. The original class symmetry is thus broken.

Breaking class symmetry also breaks object type symmetry, as the object type is now transferred to the interface. Moving a type away from its objects, to the interface breaks the type symmetry of these objects, as an object type can now represent more than one set of objects.

Breaking behavior symmetry happens when a type hierarchy breaks and objects in the hierarchy cannot be substituted one for another. Typical patterns that break behavior symmetry are Adapter, Composite, and Decorator [6].

It is easy to understand that the Adapter pattern breaks behavior symmetry because it transforms one type of object into another type. Suppose we have a list and wish to use it as a set. Since a list is not a set, the two cannot replace one another. The only way we can use a list for a set is to convert the list into the set. The behavior symmetry of the list is broken into that of the set. The Adapter pattern captures this conversion process.

The Composite pattern breaks a homogeneous type hierarchy into a heterogeneous type hierarchy by allowing two types of object to cohabit: One type is the primitive, and another is the composite of the primitive. Although the Composite pattern presents the two types of object using a common interface, the behavior of the two types is different. One cannot substitute a primitive for a composite; one can only build a composite using the primitive.

The Decorator pattern breaks behavior symmetry by allowing individual objects to have unrelated behaviors. Decorator also breaks class symmetry, as it assigns responsibilities to individual objects, not to an entire class. The structure created by Decorator is a hierarchy of individual objects with different behaviors, rather than a type hierarchy, that has a uniform behavior.

Method symmetry is broken when overriding methods break the contravariant argument rule. Castagna [3] argues convincingly for breaking this rule and that covariance and contravariance characterize two completely distinct mechanisms in that the former is for code specialization and the latter is for subtyping. He proposes to capture both covariant and contravariant arguments in multi-methods. Yet since mainstream class-based languages are single-dispatch languages, Castagna's proposal is often only partially implemented. For example, Eiffel adopts the covariant policy on both argument and result types; Java requires that both argument and result types vary in unison, either in a covariant way or a contravariant way; C++ supports only covariant result type and does not care about argument type. Patterns, such as Override-Overload Method Pair (see www.curbralan.com), are introduced to simulate multi-methods in single-dispatch languages to support both covariant and contravariant method definitions.

There are more method symmetry breakers in [6] than there initially appears. For example, Template Method breaks method symmetry by separating the invariant part (template) of a method from its variant part (method steps). The same symmetry-breaking footprints can be found in Eiffel's Loop Invariants and other design patterns, such as Visitor, Interpreter, and Iterator [6]. Or should it be that all these method-breaker patterns are variations of Loop Invariants? It does not matter which answer is true or most appropriate; the heart of the matter is that method symmetry needs to be broken to allow flexible and reusable design. Other method breakers are Chain of Responsibility and Command [6], which break a method into sub-methods, again, to facilitate design flexibility.

Yet, while design patterns break symmetries enforced by original language features, they create their own local symmetries, and in so doing, they add extra features on top of languages.

The good news is, with judicious use, design patterns can provide some extra, useful programming utility; the bad news is, they can be so easily misused or, at the best, overused by pattern enthusiasts. The worst-case scenario is there are potentially an infinite number of design patterns resulting from the finite number of language features, all equally arbitrary; how do we know which ones are good and which ones are bad? Understanding the relationship between language features and design patterns in terms of symmetry and symmetry breaking may provide he answer to that question.

Conclusion

In natural, as well as artificial systems, symmetry reigns supreme. This article has shown that class-based OO programming features create symmetries, whereas class-based design patterns break them. The relationship between language features and design patterns, as characterized by a more fundamental relationship between symmetries and broken symmetries, suggests a new way of understanding and viewing software design. The next time you are designing a program, think carefully about which symmetries you want to preserve and which ones you want to break, and why you want to do so. In a broad stroke, software design is fundamentally about making or breaking symmetry. C

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Liping Zhao (liping.zhao@manchester.ac.uk) is a senior lecturer in the School of Computer Science at the University of Manchester, U.K.

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COSTS AND BENEFITS OF XBRL ADOPTION: EARLY EVIDENCE

Financial reporting via XBRL is a low-cost method for increasing transparency and compliance while potentially decreasing a firm's cost of capital.

By Robert Pinsker and Shaomin Li

The ability to acquire, communicate, and disseminate business information is vital for investor and management decision making. Today's growing amount of information and diverse formats in reporting business and financial data makes collecting and publishing it all a major challenge for all organizations in all countries. Until recently, there was no standard format for communicating accounting information [8]. As a result, organizations had to manually assemble it from often-incompatible information systems to prepare financial reports [7].

The Extensible Markup Language (XML) was created to provide increased data accessibility to large numbers of users, especially in Web browser format—without having to re-key the information. XML and its derivatives have become increasingly important data formats for storing and exchanging business data among various systems on the Internet [2]. However, using XML to report accounting information is difficult due to a number of design issues. For example, writing an XML schema to suit a company's internal, inter-company, or external reporting is a tedious job involving a demanding mental workload for most systems engineers [3].

The eXtensible Business Reporting

Language (XBRL) is a nonproprietary Web-based XML derivative used to tag both financial and nonfinancial data and give it context (www.xbrl.org). Data tags provide information about the facts in the tags. The tags map to a data dictionary defined in the appropriate taxonomy. XBRL means reuse of data, resulting in improved accessibility, interoperability, and efficiency, potentially yielding significant time and cost savings for the adopting organizations. Additionally, XBRL is viewed by many in the accounting profession as a way to address recent international legislation and regulations (such as the Sarbanes-Oxley Act of 2002) aimed at corporate accountability, financial reporting transparency, and earnings management [1]. Yet there has been a paucity of empirical research providing insight into XBRL adoption and implementation.

Even as XBRL adoption has progressed in the U.S. (such as the Federal Deposit Insurance Corporation's call-report requirement for banks and the Securities and Exchange Commission's voluntary filing program), such adoptions have affected only a small percentage of organizations and have occurred at a slower pace than in other countries. For example, Chinese and Japanese stock exchanges are beginning to require member companies to file their information in XBRL. For regulators, the benefits of increased efficiency (through reduced data re-entry and increased accessibility) are somewhat predictable. However, for companies (both public and private) operating in environments where XBRL is not required, the actual benefits and related costs are less apparent.

Interview Questions

We are interested in learning your expert opinions on the following three issues:

Adoption process

What was the purpose of your XBRL adoption?
What factors affected XBRL adoption?
Who decided on adoption?
How were the decisions made?
How difficult do you think the XBRL adoption was for your company? Why do you think this was so?

Effect of the adoption

What were the anticipated positive effects of XBRL adoption?
What are the perceived positive effects of XBRL adoption?
What are the actual positive effects of XBRL adoption?
What were the anticipated negative effects of XBRL adoption?
What are the perceived negative effects/risks of XBRL adoption?
What are the actual negative effects of XBRL adoption?

Capital costs and transparency

What factors affect the cost of capital? Cost of capital is the incremental cost of raising money through debt financing or equity offerings.
How important is the transparency of your financial information to you?
How important is the transparency of your financial information to top management?
What do you believe are the positive effects of transparency?
What do you believe are the negative effects of transparency?

Interview questions.

Here, we report the results of interviews (phone and email) with four business managers involved in XBRL adoption in Canada, Germany, South Africa, and the U.S.[1] Our aim in doing this research is to help business executives and financial information managers better understand the costs and benefits of XBRL adoption. The questions (see the table here) were created to gather critical information about the adoption process, impact of adoption, financial results, and any potential transparency of information gains as a result of adoption. Although interviewing only four companies is a small sample, the study helps identify important issues in XBRL adoption and provide an opportunity to learn from the experience of these early adopters.

Survey Results

Three of the four adoptions we studied involved publicly traded companies. All four adopted XBRL for financial-reporting purposes (as opposed to some internal focus). All four contracted a big-four CPA firm and software vendor to help with implementation issues involving compliance with generally accepted accounting principles and company-specific technical issues. All four can be viewed as "early adopters," given the few completed XBRL adoptions as of early 2005. Finally, all four indicated the adoption process was fairly easy while acknowledging that a thorough understanding of the XBRL framework was needed beforehand and that XBRL was not part of their existing enterprise resource planning systems.

Sources for the decision to adopt XBRL ranged from the IT department (in the German company) to several individuals in top management (the other three companies). This finding indicates XBRL adoption may reflect the diversity of international corporate cultures.

Survey respondents from the three non-U.S. companies said that both the anticipated adoption benefits and the actual benefits involved cost savings through a variety of sources. For example, one respondent identified the source of XBRL-related cost sav-

[1]We solicited potential interviewees through an XBRL listserve.

The U.S. company was entirely concerned with improving its position within the public equity market, *whereas its non-U.S. counterparts were more concerned with lowering operating costs and appearing less risky to capital providers.*

ings as increased processing capability and decreased data redundancy. Others identified cost savings through increased efficiency (less data redundancy) and decreased costs of bookkeeping. One respondent identified a reduction of 30% of bookkeeping staff; the affected employees, he said, were transferred to analysis positions and not terminated. The time needed to generate financial statements was reduced from five to six days per statement to 15 minutes or less.

There was a consensus among the non-U.S. companies that the efficiencies that resulted from adoption lowered operating costs. Their strong technology capabilities enabled them to quickly reduce the costs of adoption. The lower costs, in turn, were believed by the respondents to have lowered the perceived riskiness of the capital-provision decision for capital providers.

The perspective of the respondent from the U.S. company differed from her non-U.S. counterparts. Rather than focusing on operating costs, she considered XBRL adoption a key marketing tool for reaching the company's potential investors. Ahead of any regulation requiring XBRL adoption, she indicated the adoption would position her company as a "thought leader," or innovator in the equity market. She expected that more efficient marketing and a better position in the market would lead to a broader base of potential investors and a lower cost of capital. This perspective can be interpreted as an indirect link between XBRL adoption and reduced cost of capital.

The difference in perspectives between U.S. and non-U.S. survey respondents is anecdotal evidence of a U.S. focus on the equity market vs. a non-U.S. focus on internal efficiencies and capital providers. Related accounting literature generally reinforces this evidence, indicating U.S. companies undertake projects that would position them to be perceived as leaders in the equity market in order to raise capital at lower cost compared to non-U.S. companies' focus on the overall riskiness to their companies of debt [6].

Negative Factors

All four respondents also cited uncertainty in an unproven technology—XBRL—and the taxonomy and costs—time and money—needed for success as negative factors affecting their adoption decisions. However, post-adoption, the respondents viewed the risk and costs as low. This view reflects the fact that the respondents were all technically savvy early adopters. Less uncertainty (risk) eventually led to quick adoption of XBRL technology, despite it being an unproven technology. Thus, there was a post-adoption consensus that the adoption process was fairly easy. This finding may help dispel the commonly held notion among senior managers that every new technology adoption is risky and costly.

We included questions regarding company financial reporting transparency that reflected the accounting literature in the area, as well as the XBRL advocates' claim that XBRL use results in increased transparency (see www.xbrl.org). The increased accessibility to information provided by XBRL use has been conceptually linked in the literature to increased levels of reporting transparency [4]. Further, XBRL use as an investor search technology has been found to increase the transparency of the reported information in an experimental context [5].

The survey responses reflected a consensus of the importance of transparency of both financial and nonfinancial data (as a reason for adoption). The U.S. respondent went so far as to relate increased reporting transparency to an increased level of trust between management and potential investors. This finding can be considered positive news for U.S. investors in the wake of recent corporate accounting scandals, most notably at Enron and WorldCom.

Other Findings

The three respondents from publicly traded companies indicated that they believe XBRL adoption gave them a competitive advantage over their competitors without XBRL. They viewed XBRL as a key emerging financial-reporting technology and anticipated a "first-mover" advantage in the market due to adoption related to the cost of capital. The respondents apparently viewed XBRL as a technology that could help their companies differentiate themselves from their competition in the capital markets.

Finally, the South African company adopted XBRL to help it comply with impending domestic legislation and regulations (such as the Electronic Communica-

tions and Transactions Act of 2002). Although XBRL was not specifically required, the company adopted it (ahead of its competitors) due to its extensibility and compliance capabilities with international financial reporting standards. The respondent from the U.S. company noted that regulation would significantly stimulate adoption. This has yet to occur, but the U.S. Securities and Exchange Commission's voluntary XBRL filing program (www.sec.gov/xbrl) has stimulated corporate interest in XBRL.

Consistent Across Countries

Our survey results appear to be fairly consistent across countries, a result contrary to the generally heterogeneous corporate cultures in an international sample. Perhaps the two most notable insights we derived were the diverse reasons for adopting XBRL and the perceived low cost of adoption. They suggest there may not be a single right way to make the adoption decision. It may come from top management or from a company's IT managers, depending on corporate culture, technology savvy, and other factors. The implication for executives and IT managers is that a "best practice" may not exist for every company in all circumstances. Companies must find the most suitable reasons for themselves.

The low-cost perception concerning SBRL adoption may reflect the fact that managers and executives are more technology literate than they have ever been before. Thus, companies should not overestimate the cost and difficulty associated with XBRL adoption. Even though the result may be due to the technical savvy of the sample companies we surveyed, it does pave the way for other companies to realize that cost alone does not appear to be a prohibitive factor in adoption.

Another result from the survey was that all respondents believed XBRL adoption would increase the transparency of their data in the marketplace, with the three publicly traded companies indicating a perceived first-mover advantage. Lowering a company's cost of capital, whether its source is private or public, is an ongoing battle. By making company-reported information more transparent to current and potential capital providers, survey respondents believed such transparency would reduce the uncertainty and risk of providing capital to the company and thus lower its cost of capital. Similarly and consistent with prior accounting literature, the U.S. company was entirely concerned with improving its position within the public equity market, whereas its non-U.S. counterparts were more concerned with lowering operating costs and appearing less risky to capital providers. Even though these perspectives diverge, each represents an important factor in key strategic business decisions.

The findings also point to a paradox. XBRL International, an international consortium of CPA companies, software vendors, and regulators, supports XBRL adoption efforts. Furthermore, XBRL technology has been available since the late 1990s, yet there was a relative paucity of adoptions worldwide as of early 2005. This may be due to the lack of insight and guidance regarding the various adoption issues.

Conclusion

The survey results we've reported here provide XBRL adoption insight for IT practitioners. However, caution regarding them is also warranted due to the nature of the study (a qualitative survey based on a small number of interviews); one should not, for example, make statistical inferences. Still, the results are especially useful for two main reasons: an international sample and the survey being conducted in a very early stage of XBRL adoption. They represent timely information for companies embarking on or about to embark on the adoption process. C

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Robert Pinsker (rpinsker@odu.edu) is an assistant professor of accounting at Old Dominion University, Norfolk, VA.
Shaomin Li (sli@odu.edu) is a professor in the Department of Business Administration at Old Dominion University, Norfolk, VA.

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The Contribution of Critical IS Research

By Bernd Carsten Stahl and Carole Brooke

Solving ongoing external problems may require looking inward first.

A new information system is introduced to General Medical Practitioners' (GPs) practice to ease the administrative burden and to help them submit electronic claims. The system is developed and implemented by a central department after very limited consultations with the users. It turns out the main benefits accrue in the central IS department and there are very little benefits for the envisaged users. External suppliers follow the requirements analysis of the central department and optimize their own outcomes. The end users, the GPs in question, grow disillusioned with the system, and start to resist it. The system remains in place because of the power of the central purchasing authority but never delivers the promised benefits.

Does this story sound familiar? It may be because it has been published (case 3 in [4]). It may also be because it is very typical in many respects. There are the common ingredients of system failure: lack of communication, lack of user involvement, differing agendas, political power games, to name just a few. Many IT practitioners will be familiar with these factors. But the question remains: what can be done about such problems?

Here, we suggest that a suitable and novel way of addressing such organizational IT problems is the "critical approach." The word "critical" can have a variety of meanings when applied to IT. Software can be mission critical, which means "very important." Systems analysts are supposed to be critical thinkers, suggesting they should spot logical flaws in

Engaging with the critical approach "therefore" means that one must question the very values and assumptions that form the basis of one's activities. *This is never easy; indeed for many of us it is next to impossible.* It also requires us to take a step back from our day-to-day worries and to rethink our place in life. There is no guarantee this will be an enjoyable experience.

requirements or design. Users can be critical of systems, implying they do not approve of them. However, in academic texts, the term "critical" (as in "critical theory" or "critical social sciences") has taken on a more specific meaning. The critical approach to information systems has been known to researchers for quite a while and is generally acknowledged as an alternative to "positivism" or "interpretivism."

Despite growing attention to critical research in academic circles, there seems to be little corresponding activity among IT practitioners. We believe that IT/IS practice could benefit greatly from the critical approach. Here, we investigate why little practical activity is taking place in the area. We also demonstrate why critical research would be beneficial for IT professionals and consider how practitioners can benefit from critical ideas without falling into the dual trap of either trivializing the approach or becoming lost in its complexities.

Guiding questions of the critical approach.
Does the technology lead to empowerment of any or all of the stakeholders?
What should my role (as a developer, analyst, manager) be to facilitate empowerment?
Are there structural problems (ideological assumptions) that unnecessarily limit the solution space?
Which particular interests are served by the current approach and how can I ensure a broad understanding of the problem?
Do I understand my ethical obligations and do I see a way of discharging my ethical responsibilities?

Obstacles to the Critical Approach

One of the first problems anyone who wants to do critical research or practice in IS will encounter is that there is no generally accepted and unequivocal definition of the term [3]. However, there are some characteristics of most critical research that we assume to be uncontroversial. The arguably most important property of critical research is that it is based on a critical intention to make a difference. Critical research is never purely descriptive but wants to change social reality. This is based on a deep suspicion that the current state of the world is unjust and disadvantages many. Capitalism, while usually not discarded completely by critical authors, is nevertheless seen as dysfunctional in many respects and in need of revision and rethinking. A major aim resulting from the critical intention is to promote individual empowerment and emancipation [5, 8]. Due to the critical intention, critical research often centers on topics where the injustices of our current world are most visible and where critical research can make a difference. Such topics not only include the digital divide and gender issues, but also questions of organizational power or the relationship between employers and employees. This is one reason why the critical approach would be suitable for a situation like the one described in the opening remarks.

This very brief introduction will have indicated some of the reasons why many practitioners may initially be reluctant to engage with the critical approach. A central problem is that critical research is critical of the very social and economic system within which IT and related commercial activities are embedded. Engaging with the critical approach "therefore" means that one must question the very values and assumptions that form the basis of one's activities. This is never easy; indeed for many of us it is next to impossible. It also requires us to take a step back from our day-to-day worries and to rethink our place in life. There is no guarantee this will be an enjoyable experience. In addition, it can obviously run counter to organizational incentives and power structures, which are generally geared toward control and not emancipation.

Another problem is the perceived (and sometimes real) politics of critical research and its proponents. It is linked to the names of theoreticians such as the members of the "Frankfurt School" of social science (including Marcuse, Horkheimer, Benjamin, Adorno, Habermas, and others), and a number of French thinkers (including Foucault and Bourdieu to name just two). What these authors have in common is they have worked intensively with Karl Marx's writings. They are therefore perceived to be on the political left, which in management studies, and even more so in business practice, is often problematic.

A final problem with the "application" of critical thought to the practice of IT professionals is that it does not lend itself to clear and simple algorithms, methodologies, or realizations. There is no one way of critically engaging with the world. Critical thinking requires reflexivity, which means a willingness and ability to question oneself and one's own assumptions. Such reflexivity goes beyond a simple deliberation concerning the action in question. Reflexivity goes to the heart of the individual and requires them to question the basis of their beliefs. It requires self-analysis. This is threatening to many, while others dismiss it as "navel-gazing." It promises no economically useful outcomes but challenges the critical thinker every step along the way.

Advantages of Being Critical

Despite the serious obstacles to the critical approach, there are a number of advantages to it, which lead us to suggest that IT professionals should be aware of it and would benefit from using it. We distinguish between two groups of benefits: instrumental and intrinsic. The term "instrumental benefits" refers to such situations where the critical approach can lead to tangible organizational benefits, whereas "intrinsic benefits" are those where taking the critical approach can simply be described in more ideological terms as being "the right thing to do."

Instrumental benefits. The critical viewpoint is an inclusive one, which comprises individual, organizational, and social issues. It is not possible to distinguish between technical and organizational problems or between systems development and systems acceptance. On the one hand, this view thus adds complexity to the activities of IT professionals, while it enriches their understanding. This, in turn, will facilitate a new perspective on problematic issues and an enhanced understanding of them. Such a widened viewpoint is arguably desirable for IT professionals. It is part of conventional wisdom that IT professionals have a tendency to privilege the technical and disregard non-technical aspects of their activities. At the same time we know that the percentage of systems failures was, and is, large, and that in most cases the reason for failure is not technical [11]. Therefore, the main argument here is that the critical viewpoint allows the IT professional to develop a different perspective, which will help them improve practice.

Indeed, there are examples of how the use of critical thoughts can affect and improve the work of IT professionals. One of these is the application of the idea of emancipation. Emancipation can be understood as helping people achieve their potential and helping them to be free from alienation and suppression [10]. In practice, the emancipatory intention of the critical approach means that all individuals involved in the design, development, and use of a system or technology need to be able to express their viewpoints about it. While this can raise serious problems when implemented, it also points the way toward participatory methods of the design and use of technology. Participatory approaches have the instrumental advantage of maximizing the knowledge base of product development and thereby increasing the chance of success.

This line of thought can be extended into risk management. The majority of IT/IS risk management literature suggests the use of a generic list of project risks, which then must be mitigated by the project management [12]. This type of risk management covers general problems but it is incapable of being sensitive to the specific context of a given system. This is arguably the reason why the generic lists of risk factors compiled by different authors do not converge [9]. A participative approach as suggested by critical theory is capable of overcoming this problem. By incorporating the perceptions and knowledge of the majority of stakeholders, project risks are likely to be identified earlier and more thoroughly.

Finally, empowerment in its different forms can also become a business model for IT professionals. IT can be used to enable people to live more independent lives. A good illustration of such applications would be systems used to help disabled people to participate in activities of their choice [7], or e-democracy where IT supports citizens to act autonomously [6].

Intrinsic benefits should be clear enough to persuade IT professionals to at least consider the critical approach and weigh the problems of accessing it against the possible advantages. However, from the point of view of critical research, such instrumental reasoning sits somewhat uneasily with the general idea of critical research and practice. Using the critical approach to promote the goals of commercial organizations and maximize profit seems to run the danger of being self-contradictory.

There is nevertheless a good reason for using the critical approach, even when it does not promise instrumental benefits. Critical practice can be seen as the right thing to do. To understand this line of reasoning one needs to go back to the fundamental ideas of critical thought, with its aims to emancipate individuals from disempowering and alienating circumstances. While this is linked to skepticism of

capitalism, it goes beyond considerations of the economic system. The wish to emancipate is based on the recognition that others are fundamentally equal in rights and obligations to us, that there should be equality between people and that everybody deserves the chance to fulfill their potential.

This idea is closely linked to ethical reasoning. It implies a vision of justice and is closely linked to a participatory and democratic form of governance. At this stage, it becomes clear that critical research is not automatically and inevitably anti-capitalist but only aims to address issues where capitalism becomes counterproductive. A critical approach can, thus, be seen as an expression of ethics and as a necessary critical voice where market mechanisms do not live up to their promises.

It is important to realize these fundamental thoughts because they allow IT professionals to interpret critical research as a possible expression of their ethical obligations. While there is sometimes a tendency for individuals working with technology to deny or downplay their social and ethical responsibility, this cannot be said for recognized IT professionals. For example, ACM expects members to adhere to its Code of Ethics and Professional Conduct, which clearly states they must take their non-technical responsibilities seriously. They are also offered guidance by professional organizations on how to deal with such matters [2]. Critical thought requires engagement with serious moral and ethical issues and offers the IT professionals an avenue to discharge their responsibilities more fully.

Applications of Critical Thought for IT Professionals

Having attempted to interest the reader in exploring

CREATING A SPACE OF MEANING: AN EXAMPLE OF THE CRITICAL APPROACH

The case of Callco can serve as an example of how the critical approach can help address problems created by the organizational use of ICT [1]. We will refer to the guiding questions of the table in the article to demonstrate the relevance of the critical angle.

THE CASE: Callco information systems were being applied to automate many of the processes previously carried out by individual customer service advisors. The organization had implemented a widescale process of automation, removing many people from the data interface. However, they had been forced to reconsider their strategy because of poor external customer feedback (issue #1). It appeared that many jobs were being misdirected or being returned to the internal job queue further down the line (issue #1). There was little possibility to identify, let alone discharge, ethical responsibilities (issue #5). Discussions with management revealed an assumption that technology was a neutral vehicle for transmitting facts and it could be used to speed up data processing both geographically and functionally in a largely unproblematic way (issue #3). Technology was being applied so as to achieve rational transparency as a means to ensure administrative control.

THE CRITICAL CONTRIBUTION: Taking the critical stance allowed us to take a step back from the day-to-day issues of Callco and consider the roots of the problem. This was conceptualized as an issue of space and meaning. In privileging progress (that is, time, speed, or efficiency), the space to create meaning had become a blind spot of a technology that was both scientific and political in its application (issue #4). This was a crucial problem because shared meaning (for example, organizational culture) is necessary for successful collaboration. Such space can be physical space (a room where one can meet others and interact), but also intellectual (the possibility of engaging with others and exploring their thinking). The practices at Callco failed to offer a solution to the lack of space for meaning creation, but also rendered the very problem invisible.

It required external pressure (through customers) for management to become open to reconsider their basic assumptions concerning the spatial practices involved in automated systems (issues #1, 3, 4). However, once a space for dialogue had been forced upon the organization through a mini-crisis (falling custom and reputation), it created the possibility for representational space to be addressed as well (issues #2, 4). Once management acknowledged the need to create intellectual representational space, they were more willing to revisit the design of systems and procedures (issues #2, 4). Enabling the staff to reengage with meaning creation in their data processing activities produced better external customer ratings and also increased staff morale (issues #1, 2, 5). C

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and practicing the critical approach, the next question involves how this approach can be realized. The answer is likely to be somewhat disappointing to technically minded people used to applying algorithms and methodologies, which lead more or less predictably to a solution. There is no generally accepted methodology for being critical.

There are, however, some general guidelines for being critical that IT professionals can follow. Arguably, the most important is to be reflective; that is, the professional must constantly question the assumptions and results of their actions. Being critical requires one to focus inward first—referred to as reflexivity. This includes the attempt to realize what one is trying to do and why. In order to achieve this, one must take a step back from day-to-day life and the issues it brings. Part of this process is to question who the stakeholders are and who will be affected by one's action. It also means one must try to ascertain their viewpoints and incorporate these in one's decisions.

Being critical also requires the ability to interpret one's roles and activities in their social context. Technology and its intended uses are not value-neutral, but are based on many explicit and implicit value decisions [1]. These must be made as clear as possible and rendered open to potential revision. The critical approach does not offer simple answers but its main usefulness allows for asking novel questions. These questions allow the practitioner to develop a new understanding of problematic situations, which in turn is a prerequisite for creative solutions. Some of the questions that are typically asked by critical practitioners are collected in the accompanying table.

All these steps require effort, resources, and the courage to question oneself. It also requires a willingness to take others seriously, whatever their role in relation to the project. Potential stakeholders include the traditional commercial ones such as management, employees, customers, and suppliers, but they can also include local communities, relatives of employees, non-governmental organizations, among others. Such an approach can be very destabilizing because it forces us to face cultures, world views, and realities may not be compatible with our own. (See the sidebar "Creating a Space of Meaning: An Example of the Critical Approach" for a case study illustration of the guiding questions noted in the table).

The critical approach is not an easy option. It is difficult to access and difficult to realize. It requires engagement of the IT professional that goes beyond a narrowly defined understanding of technical responsibility. This is a significant challenge. However, it can also be highly rewarding because it offers new perspectives, can overcome limitations of traditional practice, and addresses ethical issues. We do not claim that being critical would easily have prevented or solved the problem of the GPs (or of the vignette included in the accompanying sidebar "Creating a Space of Meaning"). We do claim, however, that thinking about the questions noted here would help to clarify the nature of the problem and thus prepared the ground for an innovative solution. Furthermore, taking a critical stance will sensitize IT professionals to problems and issues on a wider scale and, thereby, help limit problems before and when they arise. C

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Bernd Carsten Stahl (bstahl@dmu.ac.uk) is a reader in critical research in technology in the Centre for Computing and Social Responsibility of De Montfort University, Leicester, UK.
Carole Brooke (cbrooke@lincoln.ac.uk) is a professor of organisational analysis at the Lincoln Business School, University of Lincoln, UK.

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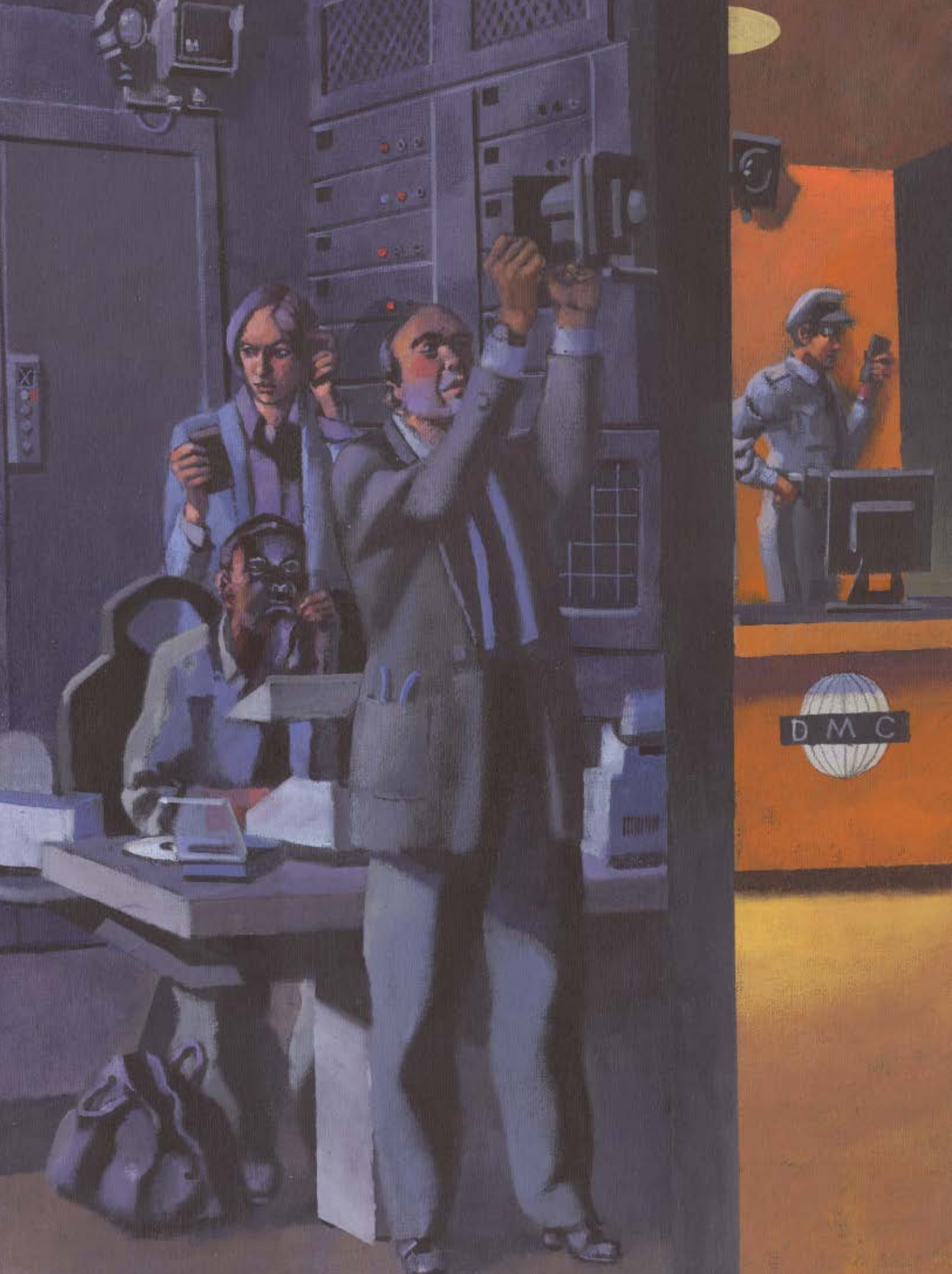
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By David Wright,
Michael Friedewald,
Wim Schreurs,
Michiel Verlinden,
Serge Gutwirth,
Yves Punie,
Ioannis Maghiros,
Elena Vildjiounaite, *and*
Petteri Alahuhta

THE ILLUSION OF SECURITY

A fictional scenario of daily life in a world networked with ambient intelligence illustrates the dark side of the technology and the need for appropriate safeguards.

While most stakeholders paint the promise of ambient intelligence (AmI) in sunny colors, there is in fact a dark side to AmI. In a way, this dark side is inherent in the very nature of AmI. Intelligent networks embedded everywhere will enable data aggregators to acquire a lot more personal information, far more than in today's world, greatly magnifying the risk of abuse of that data.

Illustration *by* John H. Howard

Most AmI scenarios illustrate its benefits. The dark scenarios, developed by the SWAMI (Safeguards in a World of Ambient Intelligence)[1] project, are different as they point out the risks that must be mediated if AmI is to be a future success story.

The scenario we present here hinges on the theft of data from a multinational company. The company suffers from the illusion of security—that is, the belief it has implemented more than adequate security measures—only to discover it has not.

A Dark Scenario

The Data Mining Corporation (DMC) has an almost perfect business model. It collects data about individuals from hundreds of sources and then sells the aggregated data back to many of those sources. Its principal sources (and clients) include insurance companies, retail chains, media conglomerates, credit-reporting agencies, mobile phone companies, law enforcement agencies, customs and immigration authorities, and intelligence agencies.

Among the ways DMC has managed to sidestep legislative and regulatory constraints on transfers of personal data is through mergers with or acquisitions of companies with their own extensive databases. DMC is headquartered in Miami, but now has major subsidiaries in London and Tokyo. It is listed on the New York and London Stock Exchanges and is considering a listing on the Tokyo Stock Exchange.

Scene 1: Management board meeting. The company secretary stands close to the iris scanner. The door opens and he enters the boardroom. The president, already there, nods a slight greeting to the company secretary who can see his boss is preoccupied. She is watching the boardroom video display, which depicts her vice presidents coming down the corridor toward the boardroom. A few seconds later, the vice presidents enter one by one and take their seats.

"Okay, let's get on with it," says the president. "Show the agenda." The agenda appears on the large wafer-thin video screen on the wall opposite the president. Three items are listed:

- Data from developing countries. (Switzer)
- Theft of data. (Perrier)
- Considerations re: listing on the TSE. (Hausmann)

Kevin Switzer, vice president for operations, speaks. "We've had complaints from the Customs and Immigration folks about the shortage and reliability of our data on people coming into the States. It mainly concerns people from developing countries. With our profiling technologies, we are able to identify anyone who might be a security risk or disposed to anti-social behavior. Unfortunately, most developing countries have no AmI networks, which makes it impossible to build up the same kind of detailed profiles of individuals like we can here in the U.S., Europe, or Japan. So the immigration authorities have been making threatening noises about refusing entry to people from countries without AmI networks." Switzer seems concerned, but then smiles. "I think we have a golden opportunity here. We can set up AmI networks in those countries as long as we are the ones to collect and process the data. You'd think most countries would jump at the chance to have networks put in place at virtually no or little cost to them, but some of the countries are quibbling with us."

"Quibbling?" asks the president, "What do you mean?"

"Quibbling about control of the data. They say if we control the data, it's tantamount to signing their sovereignty over to us. But we've been working on a deal where we copy for them the data we collect... well, some of it, at least. Our intelligence agencies would not want us to hand over everything, nor do we have to. We can offer the raw data to the developing countries, but they won't know if or how we've processed the data, especially since we do the processing here in the U.S. or in the U.K., outside their jurisdiction. They'll have to settle for what we give them."

"Okay, that sounds good to me. Any objections?" she asks the others, who remain silent. "No? Okay, then, Jacques, it's your turn. What's the latest on the theft at our London office?"

Perrier, vice president for security, shifts uncomfortably in his chair. "Well, as everyone here knows, we have a regular monthly audit of DMC's data processing activity. From the last audit, we discovered that there had been a second back-up of data immediately after the first, but we can't identity exactly the device to which the data was backed up..."

"But you know *who* made the second back-up?" asks the president.

"Umm... uh... yes. It seems likely that three of my staff were responsible for doing the regular back-ups that night. We want to ask them about this second

[1] For a detailed version of this scenario and for three other dark scenarios, see D. Wright, S. Gutwirth, M. Friedewald et al., *Safeguards in a World of Ambient Intelligence*. Springer, Dordrecht, 2008. The project was funded under the European Commission's Sixth Framework Programme. It had five partner organizations, represented by the authors. The project aimed at identifying a range of safeguards to the threats and vulnerabilities facing privacy, identity, security, trust and inclusiveness from ambient intelligence. The views and opinions expressed in this article are those of the authors alone and in no way are intended to reflect those of the European Commission.

back-up, of course, but we haven't been able to contact them. It seems all three left on holidays a few hours after the second back-up was made. They were supposed to have returned three days ago, but they haven't reported for work and they haven't answered our calls."

The president is getting angry. "And why don't you know where they are? Surely you can track them via their location implants. Everybody has to have a location implant. It's a condition of employment in our company, just like any critical infrastructure like banks or nuclear power companies."

"Yes, but their implants are inoperable. They could have been surgically removed," says Perrier.

"And what about the sensor networks in their homes and cars?"

"Yes," says Perrier. "Like other employees, they've agreed that we can check their home systems and we've done that. There's obviously nobody in their apartments, and their cars have been stationary since they left on holidays..."

"Have you checked the surveillance systems?" asks the president. "You can't go anywhere in London without being caught by surveillance cameras hundreds of times a day."

"Yes, we've been reviewing the data from the surveillance systems, too," says Perrier. "But they haven't shown up on those either. We've also checked with the airlines and railways and car rental agencies to see where they might have gone. Now we know they left for Costa Rica, but then the trail goes cold. As Kevin has just pointed out, the developing countries don't have the kind of AmI infrastructure needed to track people, so they could really be anywhere. We've also been checking with the 4G companies, but so far, there's been no data recovered on use of their mobiles."

"I don't understand how they could have got past our own security systems," says the president. "We have access control to prevent unauthorized employees from copying or manipulation of data."

"That's true," says Perrier. "The snag is that *they* were authorized. Quite a few employees have partial access, so if three or four with access to different bits collaborate, as these three appear to have done, they are able to get virtually full access to the data."

"Even so," says the president, "how did they get the data outside our headquarters?"

"With today's technology, it's easy to copy vast amounts of data in seconds onto high-capacity optical storage devices no larger than a deck of playing cards, which makes them easy to conceal on the way out of the building. It's hard to break into DMC offices, but it's not hard to get out."

"If we were exposed, it would be a complete disaster," says MacDonald, the VP for public affairs. "Among other things, it would show our clients that the profiles of our own employees are not reliable because we weren't able to predict that these few bad apples were going to abscond with copies of our records."

Max Court, DMC's general counsel, speaks up. "If we were exposed? Are you suggesting we should withhold information about this theft from the police and those whose files have been copied?"

"Of course," says MacDonald. "It's obvious, isn't it? I'd hate to imagine what it would do to our share price and our plans for a listing on the Tokyo Stock Exchange."

Scene 2: The Old Bailey, two years later. BBC1 news anchor: "And now we go to our reporter, Miles Davenport, who's been at the Old Bailey today, attending the trial involving the Data Mining Corporation and its directors. What's the latest, Miles? Has the jury returned with a verdict?"

Miles Davenport: "Thanks, Serena. No, the jury hasn't returned yet, but an announcement is expected in the next few minutes."

BBC presenter: "Miles, can you just recap for our viewers what this trial's been all about? And why is it so important?"

Miles: "Sure, Serena. It all started two years ago when *The Financial Times* broke a story about the theft of personal information on about 16 million people in the U.S. and the U.K. All this data was held by DMC, the world's largest data miner. DMC discovered that someone had broken into its supercomputers but it didn't say anything to anybody.[2] Then there was a big spike in the number of identity theft cases. People were seeing all kinds of purchases on their monthly statements for things they hadn't bought. A lot more people and companies were reporting that they were being blackmailed with threats of releases of embarrassing information. The FT got wind of this, and was able to trace the source back to a theft of data from DMC.

"At first, DMC denied everything, and then said they wouldn't comment on it because the theft was under investigation. When its share price began skydiving on Wall Street and in London, DMC had to call off plans for a listing on the Tokyo Stock Exchange. For awhile, it looked like DMC was going bust, but the U.S. government stepped in and

[2]DMC is not alone. See J. Krim, "Consumers Not Told Of Security Breaches, Data Brokers Admit," *The Washington Post*, Apr.14, 2005. See also D. Stout and T. Zeller Jr., "Agency Delayed Reporting Theft of Veterans' Data," *The New York Times*, May 24, 2006.

propped up the company. They said that national security was involved, and they could not allow the company to go bust."

BBC presenter: "Personalized services are great, of course; they save us lots of time. And so are the improvements in our security, like knowing when we are near criminals or suicide bombers, but isn't there a dark side?"

Miles: "Well, yes, there is. We have to trust companies like DMC to keep our data safe, secure, and accurate. But now we know that our data is not secure. DMC not only failed to protect our data, they were actually selling it to governments who were hunting for people with behavioral dysfunctions in case they were likely to commit a serious crime or an act of terrorism. They've also been selling the data to other companies who were using the data to spam just about everybody in the U.S. and here in the U.K. DMC claimed they couldn't be held responsible for what their clients did with the data." [3]

BBC presenter: "Thanks for that recap, Miles, but weren't there some other issues that came out during the trial?"

Miles: "There certainly were, Serena. People are entitled to see their records, but most people didn't even know about DMC, let alone the fact that they had built up such extensive records on every one of us. So, some consumer activist groups banded together to sue DMC for negligence. People had no idea just how pervasive ambient intelligence had become. We heard that in many instances the data coming from so many different ambient technology networks was often in conflict or didn't make any sense. DMC countered that its proprietary software contains an algorithm for comparing data from different sources to maximize reliability and its predictive capability, but under intense questioning from the prosecution, they admitted they could never eliminate unreliability nor could their predictions of who might be a terrorist or criminal be 100% certain."

BBC presenter: "And the DMC directors, what's going to happen to them?"

Miles: "We'll find out after the jury comes back with the verdict. The DMC president, however, has already resigned, but she went out with a golden parachute—a severance package worth a cool $100 million—and now she's apparently living in Costa Rica."

[3]cf. W. Safire, "Goodbye To Privacy," *The New York Times*, April 10, 2005: "Of all the companies in the security-industrial complex, none is more dominant or acquisitive than ChoicePoint of Alpharetta, Ga. This data giant collects, stores, analyzes and sells literally billions of demographic, marketing and criminal records to police departments and government agencies that might otherwise be criticized (or defunded) for building a national identity base to make American citizens prove they are who they say they are."

Analysis

Here, we present a methodological structure for analyzing this scenario, which could also be applied to the construction and analysis of many technology-oriented scenarios.

Situation. The objective of this scenario is to depict what is called the "illusion of security" in an AmI world a decade from now, when ambient intelligence has become pervasive in developed countries (but not developing countries), when most people embrace the personalization of services and the supposedly enhanced security resulting from the application of AmI. Although AmI offers powerful new technologies for security applications, such technologies can be undermined by determined people.

This dark scenario is a trend or *reference scenario* because it starts from the present and projects forward on the basis of to-be-expected trends and events. It is intended to be realistic or descriptive rather than, for instance, normative or extreme.

The scenario concerns the theft of personal information held by a data aggregator (DMC) by three rogue employees. Theft of identity occurs now, but the difference between such crimes today and in the future is the scale of the data involved. AmI will make it possible to gather orders of magnitude more information about virtually every person in America, Europe, and Japan. The future is also marked by an increasing concentration in the control of personal data. Thus, the risks to individuals are much greater when something goes wrong.

AmI technologies used in the scenario. The scenario makes reference to several AmI or AmI-related technologies, including:

- Biometrics, such as the iris scanners that grant admission to the boardroom;
- Networked sensors/actuators, such as those that detect human presence in cars or homes;
- Speech recognition and voice activation, such as the system in the boardroom that recognizes a command from the president of operations to show the agenda;
- Surveillance technologies including video cameras, keylogging software, location implants, biometrics, and networked sensors, that are used to monitor where employees are and what they are doing;
- Intelligent software that can analyze past behavior and preferences in order to predict needs and personalize services (which TV program to watch, which products to buy), something Serena, the TV presenter in Scene 2, views as welcome by the market;

- Networked RFIDs, sensors, and actuators for gathering data about people and the products they have or services they use. These and other AmI technologies greatly facilitate profiling of virtually everyone; and
- Fourth-generation mobile phones, which combine today's PDA capabilities with third-generation mobile technology (and much else). Such multimedia personal devices provide a wide range of services (and collect vast data), but 4G networks are not available everywhere, especially not in developing countries, like Costa Rica, to which the data thieves and, later, the DMC president decide to decamp.

Applications. The AmI technologies referenced in the scenario are used in various applications, including:

- *Security:* DMC has instituted various security measures, such as access control (to offices and software systems), key logging, proprietary software, employee monitoring and so on, to ensure the security of the personal data it collects and processes.
- *Surveillance:* Video cameras and other surveillance technologies keep watch on virtually everyone, especially in the streets and shops of London (and other cities), but increasingly in their homes too. Such technologies can be used to detect whether someone exceeds the speed limits or pilfers items from the shops, but also whether they engage in terrorism on the Underground.
- *Immigration control, counterterrorism and policing:* AmI networks are used to compile personal data and profile would-be visitors and immigrants to help officials assess whether they present a security risk or might behave in a socially dysfunctional way.
- *Personalization of services and targeted marketing:* With the prevalence of AmI networks, and the vast amount of personal data they generate, service providers can individuate their services to new levels of specificity.
- *Critical infrastructure protection:* It's hard to get into the DMC offices (but not so hard to get out). AmI sensors and actuators, biometrics, and other access control measures are used to protect critical infrastructure, such as DMC, banks, public utility networks, government offices.

Drivers. The drivers at work here can largely be derived from the motives and needs of the principal characters in the scenario and/or economic, political or social forces. DMC's management are primarily driven by the profit motive, a desire for scale (such as to be the market leader, to swallow or overwhelm competitors) and to create a situation where their clients are dependent on DMC services and products.

A second driver must be market demand, that is, there are many companies and governmental agencies that want the processed data that DMC has been supplying.

A third driver, not so dissimilar from the first, is that the data thieves are also impelled by the profit motive.

A fourth driver is respect for the law. This is (partly) indicated when DMC's general counsel expresses some disbelief at the suggestion that DMC should cover up the data theft from both the police and those whose files have been copied. In Scene 2, respect for and redress through the law is the key driver.

Yet another driver can be identified, such as the media's desire for a good story, which has the benefit of raising public awareness about the pervasiveness of AmI.

The scenario raises several issues:

Digital divide. The developed countries have AmI networks and the developing countries don't. There is a risk that this will lead to discrimination against developing countries. Intelligence agencies and immigration authorities may not admit visitors and emigrants from countries without the AmI networks needed to generate detailed profiles and a determination as to whether a person could be a security risk. The digital divide issue radiates in many directions and prompts many questions. Will the quest for perfect security really protect our societies? Recent developments suggest we are as much at risk from homegrown terrorists as from those in developing countries. Also, if immigration is restricted from developing countries without AmI networks, won't our "developed" societies somehow be impoverished because we will lack the views and experiences of those who know what it's like to live on both sides of the digital divide? If immigration is restricted, especially on the grounds of a lack of AmI-generated data, won't we inflame resentment in developing countries?

Concentration of power. DMC is the clear market leader in the aggregation and processing of AmI-generated data. It has a wide range of powerful clients. When there is a risk that DMC might collapse, the government steps in to prop up the company. When governments and client industries are so dependent on a single market player, they are at risk of being held hostage. Even if the company professes respect for the law, there is a distinct risk, whatever its declared inten-

tions, that it will act in a monopolistic way ("Power tends to corrupt."). High technology companies may fly under the radar screen of competition authorities for a long time before they are noticed, by which time they may have, like DMC, accumulated too much power.

The concentration of power manifests itself in other ways in the scenario. DMC says it is willing to establish AmI networks in some developing countries as long as DMC controls them. Developing countries, concerned about their sovereignty, will "have to settle for what we give them," says Switzer. Also, employees have "agreed" that DMC can check their home sensor networks, that is, if they want a job at DMC, they must agree. Similarly, employees must bear location implants.

Lack of public awareness. Despite the convenience of personalized services and enhancements in security made possible by AmI, most people have not comprehended just how pervasive AmI has become, nor of the scale and volume of data being generated about them by AmI networks. In the scenario, public awareness is increased as a result of the investigative reporting and media coverage of the theft of data from DMC, the resulting trial, and the high-level political intervention to stave off DMC collapse. Aroused public awareness may force changes in legislative or regulatory oversight. Hence, public awareness and the pressure of public opinion, stoked by the media, have utility as a safeguard against abuse. Unfortunately, such pressure is almost always reactive.

The illusion of security. Most people are willing to trade some of their privacy for better security. The scenario suggests that terrorism has become sufficiently serious that the intelligence agencies and immigration authorities are becoming unwilling to admit foreigners unless they have detailed information on each individual. Similarly, DMC employees seem willing to have location implants and surveillance equipment installed not only in their offices but in their homes and cars. They probably see this as beneficial in security terms.

It is ironic that DMC and its directors face a class action lawsuit on the grounds that they were negligent in securing personal data. Security would seem to be one of DMC's key strengths, one of its key selling points. DMC can hardly believe that its many security measures—video surveillance, biometrics, key-logging software, access control measures, regular audits, employee implants and so on—could fail. But the question is: have DMC executives done enough? Was their profiling of employees sufficiently rigorous so that they did not need to fear theft by insiders? We are told that it was difficult to get into DMC offices, but not difficult to get out. DMC's security defenses seemed primarily aimed at preventing breaches at its perimeter.

The company was rather less focused on the enemy within, hence the three employees (who had authorized access to the data) were able to collaborate, to copy the files and exit the premises without being challenged. Further, it seems to have been relatively easy for them to remove their location implants and to disappear without a trace. But the three employee data thieves are not the only miscreants at DMC. The senior executives also behaved unethically and illegally by not informing the police and their customers about the data theft.

Hence, we can conclude that an illusion of security prevailed at DMC and, perhaps, more widely within society as a whole. The illusion is fed by the implicit assumption that various AmI technologies and procedures will form an adequate defense against miscreants. Unfortunately, no matter how strong these technologies and procedures may be, they may still fail, especially against insiders acting in concert (both the employees and the executives).

At the societal level, we may assume that laws and regulations will protect us, but this scenario suggests that even there we suffer from the illusion of security—it takes a class action suit to bring DMC to justice. Market forces that might otherwise punish DMC are undermined because government decides that DMC cannot go to the wall. DMC has managed to acquire so much power—partly through its proprietary technology and partly through its market dominance—and has come to play so big a role in (ironically) national security that government cannot allow it to go under. But if DMC was unable to detect the security risk posed by three of its own employees, isn't the government's confidence in DMC technology misplaced?

The illusion of security is also fed by unwarranted trust. The issue of trust is not directly raised in this scenario, but it is not far away. One would think that a data aggregator, processor, and reseller like DMC would have some obligation to inform people whenever it sells data to others or takes over another company with personal data records. But this has not occurred. It seems that DMC clients, the intelligence agencies and immigration authorities, are content that individuals are not informed about what information DMC has on them, even if the law dictates otherwise.

California and a number of other states have strict laws requiring that companies do inform individuals

when their data has been compromised—but that does not mean that they *will*. Compliance will depend as much on corporate culture and, especially, ethics as on legal deterrents. Thus, to some extent, even laws and regulations can instill an illusion of security.

Conclusion

The principal conclusion we draw from this article—from the dark scenario and the analysis—is that, although we can expect amazing advances in the development and deployment of ambient technologies, there is a risk that corporate ethics in the year 2018 will not be so different from those prevalent in the year 2008, which is to say that some companies will be good corporate citizens and some won't. Similarly, some companies will have rogue employees just as they do today who are capable of undermining what might be perceived as strong security (technologically, procedurally, legally). A principal difference between today's world and that depicted for the year 2018 could be that security concerns about terrorism and antisocial behavior will be such that unless individuals have really detailed profiles compiled from data from AmI networks, they may be barred from entering a developed country. Also, while people may welcome the convenience from personalization of services and the ubiquity of surveillance technologies, they may be lulled into a false sense of security.

As mentioned in the introduction to this article, there have been few "dark" scenarios put forward by AmI experts and aficionados. The SWAMI project has taken a deliberately contrarian position with regard to scenarios that show the "sunny" side of AmI. While the authors are as enthusiastic as anyone about the potential of AmI, advances in surveillance technologies, biometrics, and fourth-generation mobile systems, they believe the AmI community, policymakers, and society must be alert to possible abuses of the technology. Constructing scenarios and using an analytical structure along the lines as noted in this article offer a useful way of stimulating dialogue about such possible abuses as well as other technology issues.

Identifying possible abuses is the first step in devising safeguards. Almost certainly, a mix of safeguards will be needed—technological, socioeconomic, legal, and regulatory and even cultural safeguards can be envisaged.[4] As a minimum, the SWAMI consortium advocates a privacy impact assessment for any projects supported by public funding. Designers of new technology should be required to factor in data protection in any new AmI architectures and networks. Legislation and regulation will probably be necessary, and one can predict that will elicit protests from those in favor of deregulation and getting the government off their backs. So be it.

If civil liberty advocates have had concerns about encroachments upon our privacy in the emerging surveillance society, they will be positively apoplectic if AmI, already being implemented in a somewhat piecemeal fashion, becomes as pervasive as its supporters believe it will. To anticipate this future, rather than react to it, appropriate safeguards should be agreed and put in place. Now is not too soon to start. To that end, the authors hope this article will stimulate interesting discussions and constructive debates on the issues it raises, including corporate ethics and privacy in the AmI space; surveillance technologies—from convenience to a false sense of security; the role of horror stories and dark scenarios in ubiquitous computing; and the risks resulting from unwarranted trust. As Thomas Jefferson said, "The price of freedom is eternal vigilance." C

David Wright (david.wright@trilateralresearch.com) is managing partner of Trilateral Research & Consulting LLP, based in London, U.K.

Michael Friedewald (m.friedewald@isi.fraunhofer.de) is a senior scientist and project manager in the Department of Emerging Technologies at the Fraunhofer Institute of Systems and Innovation Research, Karlsruhe, Germany.

Wim Schreurs (wim.schreurs@vub.ac.be) is a researcher at Vrije Universiteit Brussel in Brussels, Belgium.

Michiel Verlinden (michiel.verlinden@gmail.com) is an attorney at the Brussels Bar.

Serge Gutwirth (serge.gutwirth@vub.ac.be) is a professor of law at Vrije Universiteit Brussel in Belgium.

Yves Punie (Yves.Punie@ec.europa.eu) is senior researcher at the Institute for Prospective Technological Studies (IPTS) in Seville, Spain. The IPTS is part of the European Commission's Joint Research Centre (JRC).

Ioannis Maghiros (Ioannis.Maghiros@ec.europa.eu) is principal IST scientific officer at the IPTS.

Elena Vildjiounaite (Elena.Vildjiounaite@vtt.fi) is a researcher at the VTT Technical Research Centre of Finland in Oulu.

Petteri Alahuhta (Petteri.Alahuhta@vtt.fi) is a technology manager in the Mobile Interaction Knowledge Centre of VTT Technical Research Centre of Finland.

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[4]Spielberg's 2002 film, *Minority Report*, could be regarded as an example of a cultural safeguard. The film depicts a society, in 2054, embedded with AmI technologies, in which we hear memorable phrases such as "I'm placing you under arrest for the future murder of ...". For a discussion, see D. Wright's, "Alternative futures: AmI scenarios and *Minority Report*," *Futures 40*, (June 2008) *40*, 5.

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LOCATION-BASED SERVICES

Evaluating user perceptions of location-tracking and location-awareness services.

"Federal law enforcement attempts to use cell phones as tracking devices were rebuked twice this month by lower court judges, who say that government cannot get real-time tracking information on citizens without showing probable cause" [12]. As this news report illustrates, a new data type—location data provided by mobile devices—has captured the interest of U.S. law enforcement agencies. However, viewing location data solely from a surveillance perspective misses the point. Such data has the potential to expand many existing information services by adding a location dimension.

Even though location-based services (LBS) were predicted to become the "killer application" of mobile commerce, their dominance has not yet materialized—but is predicted to do so soon. The LBS market size has been predicted to grow exponentially from 2006 to 2010. Within this four-year time span, for example, Asia's LBS market is expected to increase from $291.7 million to $447 million [8], Europe's market from $191 million [9] to $622 million [3], and the U.S. market from $150 million to $3.1 billion [10]. LBS have been available for several years. Initially, location determination for mobile phones was solely cell-based, and location accuracy was determined by the cell size. Whereas cell-based approaches do not require modifications to the handset or network, other localization techniques, such as network-based (TOA, E-OTD), handset-based (GPS), or hybrid approaches (A-GPS), require modification to give increased location accuracy.

IN THE U.S., THE LBS MARKET SEEMS TO BE LESS DRIVEN BY USER DEMAND OR TECHNOLOGY INNOVATIONS THAN BY REGULATORY AGENCIES.

In the U.S., the LBS market seems to be less driven by user demand or technology innovations than by regulatory agencies. In 1996, the Federal Communications Commission (FCC) issued the E911 mandate intending to improve emergency responses to wireless 911 calls by determining a caller's longitude and latitude, with final implementation targeted for the end of 2005. The stated goal is providing the coordinates of an E911 caller: the location accuracy must be within 50 to 100 meters for 67% of all calls and within 150 to 300 meters for 95% of all calls [2]. At present, this level of accuracy can be provided only to a limited number of public safety answering points (PSAPs). As a result, U.S. cellular providers were fined for not meeting the long-past deadline [6]. However, once implemented, the E911 mandate will provide the technical foundation for LBS in the U.S.

In Europe, the European Commission initiated a similar pursuit in 2002 by issuing the Directive for Mobile Communication—E112—which represents the European equivalent of the U.S. E911. Even though legally binding, the European Commission has not stated any accuracy requirements or any policy regarding the localization technique to be used. In 2006, seven (out of 25) European countries were E112-operational, three had limited scope, and nine had initiated implementation and were upgrading their existing infrastructure [4].

Generally, the slow adoption of LBS has been explained primarily by three causes. First, the implementation of more accurate localization techniques (such as E-OTD, U-TDOA, or A-GPS) through providers has taken longer and has been more costly than expected. Second, the few available LBS applications display long response times, often too long for users to handle. And third, users are concerned about privacy issues that are an inevitable side effect of LBS. Whereas other studies have demonstrated the impact of privacy concerns on LBS, for our study we chose to examine LBS in an environment that was not affected by slow response times or imprecise localization information. We analyzed LBS in an experimental laboratory setting that provided faster transmission rates than any currently available cellular phone infrastructure and higher localization accuracy than mandated by the FCC in its E911 mandate.

Location-Based Services

Location-based services are any service that takes into account the geographic location of an entity. First, the term "entity" means the object triggering location information can be human or non-human. A pallet of groceries is, for instance, a non-human object that often needs to be tracked for logistical purposes. The Germany-based METRO Group, after a comprehensive pilot project with suppliers, warehouses, and retail stores using various generations of RFID to track pallets along the entire process chain, recently completed its rollout to 180 locations [5].

Second, there are always at least two entities involved in a location-based service request—just like there are at least two people in a phone conversation. In a generic geographic grid (such as longitude and latitude), entity A is always in relative position to entity B. Moreover, each of the entities can be either static or moving. Static can imply two things: either they are truly static (such as retailers) or

they are only temporarily static (such as a parked car).

Third, one of the entities, whether human or non-human, is always the object of LBS, that is, it is the entity about which location information is recorded. And fourth, one of the entities is always a recipient of the location information. LBS researchers distinguish between location-tracking services and position-aware services [1]. Location-tracking services provide information about a user's whereabouts to entities other than the user, while location-aware services supply the user (the information requester) with personal location data. In the case of location-aware services, the location-information-causing entity is the recipient, whereas for location-tracking services, an external third party requests and receives location information about another entity. A car navigation system is a location-aware service. Here, location information is provided to the requester (the driver) who, in return, receives real-time navigational services. Other examples of location-aware services include location-sensitive billing (paying while passing toll stations), and location-specific store advertisements sent to a consumer's mobile phone when the person is in proximity. An example of location-tracking services is UPS's truck-tracking system, where location information for each truck is used to increase fleet management efficiency.

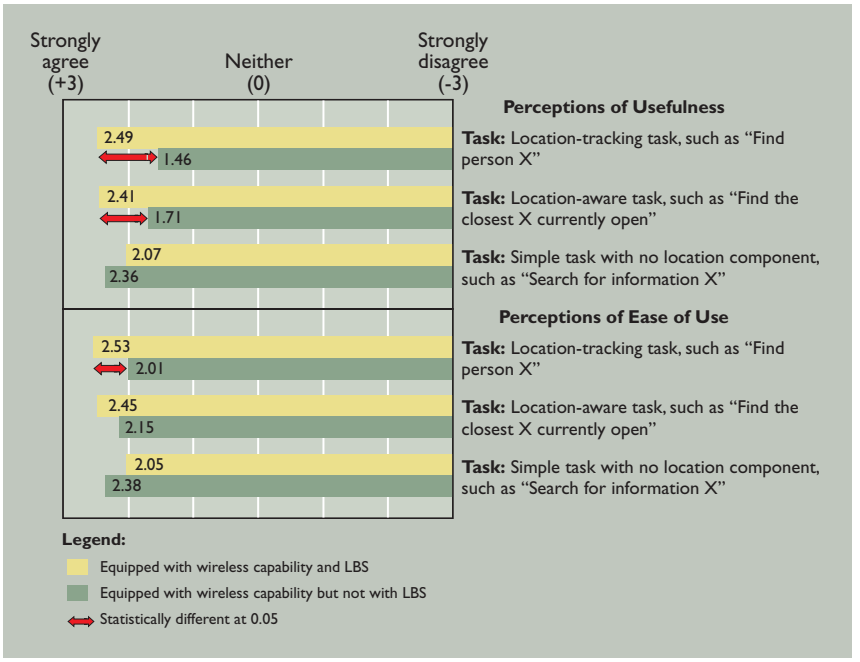

Figure 1. Usefulness and ease of use perceptions toward differing tasks.

The distinction between location-tracking and location-aware is important—not only from a technological viewpoint but also for other reasons. Whereas location-tracking services focus on particular coordinates, location-aware services go a step beyond: they also include the coordinates of the surrounding context and are expected to provide a better socio-technical fit. Thus, consumers may have different perceptions associated with each service and may find one form of service more attractive than the other or may simply detect that one form of service contributes more to their individual efficiency and effectiveness than the other. To examine these questions, we conducted an empirical study of the potential differences between location-tracking and location-aware applications. We were particularly interested in differences in performance and in perceptions of usefulness and ease of use. In addition, we also examined "traditional" (non-location) services, such as browsing the Web for information and writing/sending email, to provide a foundation for comparison. For meticulously singling out effects between location-tracking and location-aware services, a laboratory experiment has the advantage of achieving control over disturbing (or external) effects that allows for examining efficiency and effectiveness gains of LBS in the most accurate way.

An Empirical Study

The experiment involved 58 subjects, of whom 36.2% were female and 63.8% male. The majority of subjects was between 19 and 23 years old (93.2%) and had either moderate or intensive experience (> 93.1%) with at least one of three technologies: Internet, computers, and cellular phones. Every subject was equipped with a wireless PDA and randomly assigned to one of two experimental groups: one had location-tracking and location-aware functionalities, while the other did not and was provided only with wireless connectivity.

The "wireless" experimental zone spanned two buildings and a courtyard in between, totaling 80,525 square feet (7,481m^2). Within this zone, wireless Internet accessibility at a transmission rate of 11Mbps was supported (using WiFi 802.11a). The level of localization accuracy at any point throughout the network averaged between 10 and 20 meters using cell-based localization techniques.

Every subject was given the same set of three tasks: location-tracking (find a moving person); location-

sensitive (find the closest office that is currently open); and those that did not have a location component inherent to them (such as checking for weather information, writing an email message)—all embedded in an encompassing scenario.

We measured performance, usefulness, and ease-of-use perceptions associated with the tasks. For example, we expected that individuals would perceive a technology with wireless and localization capability as more useful for finding a moving person than a technology with wireless capability only. In the same vein, we anticipated some tasks, such as checking weather information, were independent of the availability of LBS. Every subject underwent a 30-minute training session prior to usage. All received their first task (out of three different types of tasks) via email after some randomized amount of time. In order to avoid grouping and learning effects, task order and the time between issuing tasks were randomized. After every task fulfillment, subjects were asked to rate their perceptions of usefulness and ease of use. Overall, each subject spent approximately three hours participating in the study.

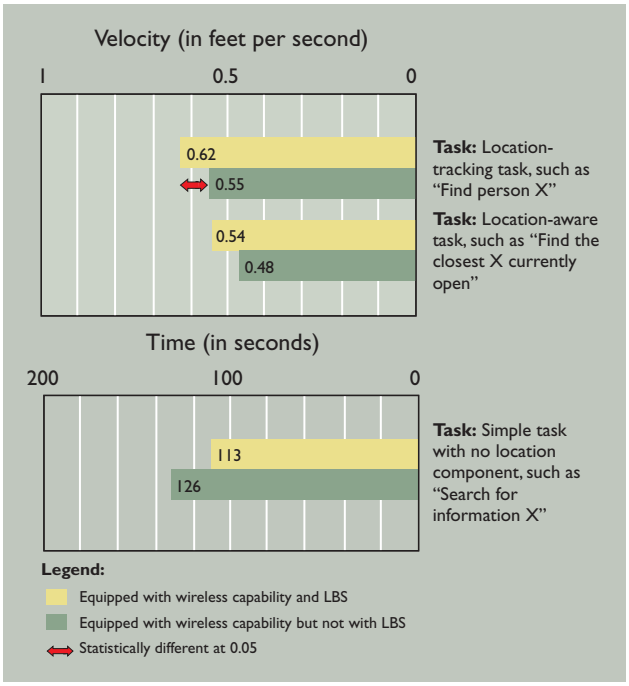

Figure 2. Task performance of differing tasks.

Task performance—the time it took for the subjects to complete a task—was measured automatically by the system. Because location-tracking and location-aware tasks stipulate that at least one of the participating entities is moving, the system also recorded geographic information. For example, a task that required a subject to find a moving person recorded not only location measures of the subjects at event time but also location measures of the (moving) person to be found. This was necessary in order to adjust time measures based on a subject's distance in relation to another person or place when executing the task. Adjustments were operationalized by calculating the velocity (the distance-time ratio) of the solution.

Four interesting outcomes were observed (see Figures 1 and 2). First, location-tracking capabilities displayed a high level of perceived usefulness and ease of use, along with an increased level of performance that was significantly different ($p < 0.05$) from their control counterparts equipped only with wireless capability. We observed that subjects were surprised by the possibility of supporting a traditional "seek" task with the help of information technology. Having a person's location information available with the press of a button was an overwhelming experience—as confirmed by some informal interviews conducted after the study. It typically took subjects one "round" of location tasks to understand the depth of the application and that the wireless system was tracking their geographic whereabouts throughout the experimental zone. Subjects expressed both enthusiasm and concern. They were fascinated by the technical possibilities and alarmed by the prospect of someone tracking their movements.

Second, with regard to location-aware services, subjects also said they were convinced of their usefulness—more so than the corresponding control group (see Figure 1). Though the interfaces for both location-tracking and location-aware functionalities were very similar, subjects equipped with location-aware capabilities did not report a significant higher level of ease of use (see Figure 1). Interestingly, subjects equipped with location-aware services did not perform significantly better than those without (see Figure 2). A possible explanation for this finding may lie in the experimental setup, more specifically in the geographical arrangements of the offices. Because of the size of the experimental cell, offices were not far apart from each other. Thus, the likelihood of subjects finding an open office (the task at hand) was not sufficiently different between LBS-assisted and unassisted searching.

Third, for simple tasks (those that did not contain a location component), perceptions of usefulness and ease of use did not expose any statistical difference (see Figure 1). The same was true for performance measures (see Figure 2, bottom). Here, subjects performed the same, irrespective of whether or not LBS were available. These outcomes were to be expected, as the sole reason for including simple tasks into our study was to provide a cross-check instrument for comparison purposes.

Overall, and as a final finding, subjects (with or without LBS) were highly motivated to partake in the experiment (even though it took more than three hours to complete). Throughout the study, the level of enjoyment among participants remained high to extremely high (88%), which indicates people were very interested in using a technology innovation providing LBS.

Conclusion

The localization factor has always been mentioned as one of the fundamental factors that differentiates m-commerce from e-commerce. However, until now, this prophecy has materialized only in Asia, in markets such as Japan and South Korea. In Europe, cell-based LBS have been around for some time, however, even for those services consumers are reluctant to pay more than for a text message [11]. More accurate localization techniques are only selectively available, as they not only require tremendous network investments but also a Pan-European strategy among operators. Therefore, an uptake of LBS is expected to become visible with the introduction of Galileo in 2008—the European equivalent of the U.S. GPS system. In the U.S., equivalent growth is expected to materialize with the completion of E911 implementation, with a revised deadline for full compliance of 2012 [6]. Among the U.S. cellular phone providers, only Sprint Nextel, considered to be the first mover in the LBS market [7], offers audible and visual navigation and mapping services to its customers (location-aware). On the business-application side, it offers viewing and monitoring of employee locations in real time on a zoomable online map (location-tracking).

We examined LBS in a laboratory setting that was not affected by slow response times or imprecise localization information. Removing real-world technical problems allowed us to focus on the pure effects of LBS on users' perceptions, as well as efficiency gains. Segregating between location-tracking and location-aware services demonstrated that differences do indeed exist between them. Location-tracking capabilities make an individual's life easier by being more useful, easier to use, and generating higher efficiency. Location-aware capabilities, on the other hand, seem not as valuable. Even though efficiency effects were observable, they turned out to be not significant. Nevertheless, subjects were highly intrigued by LBS capabilities, and the experiment left them with a formative impression. Along with enthusiasm, however, privacy concerns immediately followed, and individuals realized services that support navigational help can also be used to gain information about the navigator's whereabouts. More specifically, and from observation during the study, one would expect that people are willing to provide their location information to providers, but are hesitant to provide the same information to another entity. As this was not the focus of our study, we refer to preliminary findings of another of our studies, which shows consumers are inclined to forgo privacy if they consider the resulting services received sufficiently useful. The E911 emergency service is an instance of where the value of the service should override privacy concerns. For many services, however, where the individual benefit is not as apparent (for example, promotional offers from stores in the vicinity), consumers have a strong tendency to reject location-aware services. As a consequence, privacy considerations, besides efficiency gains and attitudinal perceptions, are likely to be a major determinant in the success of LBS. C

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Iris A. Junglas (ijunglas@uh.edu) is an assistant professor of decision and information sciences at the C.T. Bauer College of Business, University of Houston, TX.

Richard T. Watson (rwatson@terry.uga.edu) is the J. Rex Fuqua Distinguished Chair for Internet Strategy in the MIS Department, Terry College of Business, the University of Georgia, Athens.

By Robert LaRose, Nora J. Rifon, *and* Richard Enbody

PROMOTING PERSONAL RESPONSIBILITY *for* INTERNET SAFETY

Online safety is everyone's responsibility—a concept much easier to preach than to practice.

How can we encourage Internet users to assume more responsibility for protecting themselves online? Four-fifths of all home computers lack one or more core protections against virus, hacker, and spyware threats [6], while security threats in the workplace are shifting to the desktop [7], making user education interventions a priority for IT security professionals. So, it is logical to make users the first line of defense [10, 12]. But how?

Here, we present a framework to motivate safe online behavior that interprets prior research and uses it to evaluate some of the current nonprofit online safety education efforts. We will also describe some of our own (*i*-Safety) findings [4] from a research project funded by the National Science Foundation (see Table 1).

Threat Appraisal: The Fear Factor

The most obvious safety message is fear. This strategy is found at all online safety sites in Table 1. Sometimes it works. Among students enrolled in business and computer science courses, awareness of the dangers of spyware was a direct predictor of intentions to take protective measures [2].

More formally, threat appraisal is the process by which users assess threats toward themselves, including the severity of the threats and one's susceptibility to them. Examples of these and the other user education strategies found here, along with the names of related variables found in prior research and empirical evidence supporting them, are shown in Table 2. The subheadings in the table are organized around the headings in this article and reflect key concepts in Protection Motivation Theory (threat appraisal, coping appraisal, rewards and costs), the Elaboration Likelihood Model (involvement), and Social Cognitive Theory (self-regulation). The interested reader will find an overview of these theories in [1].

Name	Sponsor	URL
Staysafeonline	National Cyber Security Alliance	www.staysafeonline.info
iSAFE	U.S. Department of Justice	www.isafe.org
CyberAngels	The Guardian Angels	www.cyberangels.org
Cybersmart	National Cyber Security Alliance	www.cybersmart.org
WiredSafety	Parry Aftab, The Privacy Lawyer™	www.wiredsafety.org
GetNetWise	Internet Education Foundation	www.getnetwise.org
Itsafe	U.K. Government	itsafe.gov.uk
Consumer Information Security	Federal Trade Commission	www.ftc.gov/infosecurity
Us-Cert.	Homeland Security	www.us-cert.gov
i-Safety	Michigan State University	www.msu.edu/~isafety

Table 1. Online safety user education sites.

It is unfortunate that communication about risk is surprisingly, well, risky. It often fails to motivate safe behavior or has weak effects. And there can be "boomerang effects," named for the shape of the nonlinear relationships sometimes found between safe behavior and fear [8, 11]. Moderate amounts of fear encourage safe behavior. Low amounts of fear diminish safety, because the threat is not seen as important enough to address. However, intense fear can also inhibit safe behavior, perhaps because people suppress their fear rather than cope with the danger. In our own research involving students from social science courses (who were probably not as knowledgeable as students depicted in [2], but perhaps closer to typical users), we found a boomerang pointing in the *opposite* direction. Moderate levels of threat susceptibility were the least related to safe behaviors like updating security patches and scanning for spyware, while users with both high and low levels of perceived threat were more likely to act safely. The point is, without knowing the level of risk perceived by each individual, threatening messages have the potential to *discourage* safe behavior.

Coping Appraisal: Building Confidence

Users also evaluate their ability to respond to threats by performing a coping appraisal. Building self-efficacy, or confidence in one's abilities and in the safety measures used, is perhaps the most effective education strategy. Self-efficacy is the belief in one's own ability to carry out an action in pursuit of a valued goal, such as online safety. Perceived behavioral control is a related concept that builds on the notions of controllability and perceived ease of use to predict intentions to enact safety protections [2]. Self-efficacy is distinguishable from "actual" skill levels in that we may feel confident tackling situations we have not encountered before and, conversely, may not feel confident enacting behavior we mastered only during a visit from the IT person months ago.

Beliefs about the efficacy of safety measures are also important. It's called response efficacy in the present framework although others have identified it as the relative advantage of online protections [5]. Our confidence in our computer's capability to handle advanced protective measures (computing capacity in [5]) is another response efficacy issue. Self-efficacy and response efficacy have the most consistent impact on safe behavior across many safety issues, and we [4] and others [2, 5] have verified their importance in the online safety domain.

Efficacy has a direct impact on safe behavior, but also interacts with risk perceptions. Fear is most likely to work if the threat information is coupled with information about how to cope with them, since the coping information raises self-efficacy. When messages arouse fears but don't offer a rational means for dealing with the fear, people are likely to deny the danger exists or is unlikely to affect them [11]. In Internet terms, that defines the "newbie."

Not all user education sites include self-efficacy messages; some that do set unrealistic expectations: "You can easily keep yourself safe if you just perform these two dozen simple network security tasks daily." Still, persuasion attempts are a proven approach to

Strategy	User Education Example (Source)	Empirically Verified Variable [Citation]
Threat Appraisal		
Emphasize Threat Susceptibility	Nearly all computer systems are susceptible to viruses, Trojan horses, and worms if they are connected to the Internet (Staysafeonline)	Threat susceptibility [1] Awareness [1, 2]
Emphasize Threat Severity	You could lose important personal information or software that's stored on your hard drive (Consumer Information Security)	Threat severity [1]
Coping Appraisal		
Build Self Efficacy	Install firewalls for your family—it is not difficult. (Cybersmart)	Self-efficacy [1, 2, 4] Controllability [2] ease of use [2] Perceived behavioral control [1, 2]
Build Response Efficacy	By having a firewall on guard, coupled with up-to-date AVS, this can repel the vast majority of attacks from the outside. (Itsafe)	Response efficacy [1, 4] Perceived usefulness [2] Relative advantage [5]
Rewards/Costs		
Downplay Rewards of Unsafe Behavior	So what if you have to reregister every time you visit a Web site? What do you get out of personalization anyway? (i-Safety)	Not tested
Minimize Costs of Safe Behavior	Safety protections are easy to use and take only moments each day. (i-Safety)	Perceived ease of use [2]
Highlight Benefits of Safe Behavior	You will find that a safe computer will run better and cost you less money and effort in the long run (i-Safety)	Attitude toward behavior [1, 2] Image [1, 5] Visibility [5] Trialability [5]
Involvement		
Make Safety Relevant	Keeping your computer safe is the key to maintaining your privacy (i-Safety)	Involvement [This article]
Self Regulation		
Activate Social Norms	A mentor is a student who has received the valuable Internet safety information that i-SAFE offers, and teams up with other students (i-SAFE)	Perceived social norm [1, 2]
Stress Responsibility	A call to action: be a cyber secure citizen! (Staysafeonline)	Personal responsibility [4] Moral compatibility [1, 5]
Build Good Habits	Update your protections at the same time each week (i-Safety)	Habit strength [4]

Table 2. Framework for motivational user education strategies.

building self-efficacy, anxiety reduction is another, but both can backfire if safety measures are complex, are perceived to be ineffective, or have the possibility of making matters worse. The most effective approach is to help users master more difficult self-protection tasks.

Mismatches among threat perceptions, self-efficacy, and response efficacy could explain why so many users fail to enact simple spyware protections [2, 9] and also the inconsistent findings of previous research. Some may not perceive the seriousness of the threat, novice users (such as those surveyed in [9]) may not have the self-efficacy required to download software "solutions," while others may doubt the effectiveness of the protection. In a sample comprised mainly of industry professionals [5], a self-efficacy variable (perceived ease of use) did not predict intentions to enact spyware protections, but perceptions of response efficacy (relative advantage) did. Possibly the industry professionals had uniformly high levels of self-efficacy but divergent views on the effectiveness of spyware protections so only the latter was important.

Rewards and Costs: The Pros and Cons of Safety

Users perform a mental calculus of the rewards and costs associated with both safe and unsafe behavior. The advantages of safe behavior are not always self-evident and there are negative outcomes (the cons) associated with safe behavior. Safety takes the time and expense to obtain protective software and keep it updated. The negatives must be countered so that fearful users don't invoke them as rationalizations for doing nothing. We can also encourage safety by disparaging the rewards of unsafe behavior, such as those touted by parties who make unscrupulous promises if we just "click here."

Another tactic is to stress the positive outcomes of good, that is, safe behavior. Eliminating malware is in itself a positive outcome, but the secondary personal benefits of more efficient computer operation, reduced repairs, and increased productivity also deserve attention. In one study [5] a status outcome, enhancing one's self-image as a technical or moral leader, was an important predictor of safe behavior. The ability to observe the successful safety behavior of others (visibility in [5]) or

USERS PERFORM A MENTAL CALCULUS OF THE REWARDS AND COSTS ASSOCIATED *with both safe and unsafe behavior.*

to observe them on a trial basis for ourselves (trialability [5]) also encourages safety.

Involvement: Central or Peripheral Persuasion?

When users are deeply involved in the subject of online safety they are likely to carefully consider all of the pluses and minuses of arguments made for and against online safety practices. Personal relevance is an indicator of involvement. In the research we will describe, 44% of the participants said that online safety was highly relevant, but the other 56% had lower levels of involvement. However, many users (11% of our sample) did not find online safety relevant at all. Although safety involvement was related to self-efficacy (a significant positive correlation of 0.25) and to response efficacy (0.4 correlation), involvement is conceptually and empirically distinct from both.

	"Online safety is my personal responsibility"	
i-Safety Precaution	% of those who agree	% of those who don't agree
In the next month I am likely to…		
Update virus protection**	80	66
Scan with a hijack eraser*	54	43
Scan with anti-spyware*	80	66
Update operating system patches**	70	53
Erase cookies**	71	46
Use a spam filter**	68	45
Use a pop-up blocker**	84	65
Use a firewall**	80	58
Update browser patches**	65	44

Basis: An online survey administered to 566 undergraduate students in November 2004. All differences are statistically significant based on chi-square analyses (* $p < 0.05$; ** $p < 0.001$)

Table 3. Personal responsibility and online safety precautions.

Involvement matters. Along with our ability to process information free from distraction or confusion, involvement determines the types of arguments likely to succeed. Here, we argue that even minor deficiencies in involvement make a difference in response to online safety education. When involvement or our ability to process information is low, individuals are likely to take mental shortcuts (heuristics), such as relying on the credibility of a Web site rather than reading its privacy policy. That is when the boomerang effects we mentioned earlier can happen. The fear shuts down rational thinking about the threat to the point that users may deny the importance of the threat and choose unsafe actions [11]. When involvement is high users are likely to elaborate: They are likely to think arguments through, provided they are presented with clear information and are not distracted from reflection. This is known as the Elaboration Likelihood Model (ELM) [8].

"Phishcatchers" exploit ELM. The fear-inducing news that one's account has been compromised can overwhelm careful thinking even among the highly safety conscious. Spoofed URLs and trusted logos provide peripheral cues that convince users to "just click here," an action that requires little or no self-efficacy and, they promise, will be an entirely effective response. IT professionals tacitly enlist the peripheral processing route of ELM when they broadcast dire warnings about current network security threats through trusted email addresses.

However, what if the message from the IT department is itself a spoof? How can threats that attack individual desktops and escape the notice of network security professionals be countered? Next, we argue for an approach that promotes user involvement along with personal responsibility and that builds user self-efficacy.

Self-Regulation: Taking Responsibility

Behavioral theories change as unexpected new problems are encountered. A news story about our project prompted a letter criticizing "the professors" for assuming that online safety was the user's problem. This led us to uncover the role of personal responsibility. There is evidence that collective moral responsibility encourages safe online behavior [5], but not personal responsibility. Indeed, personal responsibility is theoretically an indicator of involvement [8], but we found the two were weakly correlated ($r = 0.20$), and so a different conceptual approach was required. We realized that personal responsibility is a form of self-regulation in Social Cognitive theory: Users act safely when personal standards of responsibility instruct them to.

In our surveys those who agree that "online safety is my personal responsibility" are significantly more likely to protect themselves than those who do not agree (Table 3). The likelihood of taking many commonly recommended safety measures is related to feeling personally responsible, with large "responsibility gaps" noted for perhaps the most daunting safety measure, firewall protection, and also the easiest, erasing cookies. However, surveys alone cannot establish the direction of causation. It could be that personal responsibility is a post hoc rationalization after users acquire self-efficacy and safe surfing habits, and does not itself cause safe behavior.

So, we investigated personal responsibility in a controlled experiment involving 206 college students from an introductory mass communication class. We

split the group into high- and low-efficacy conditions at the median value of a multi-item index. We controlled for involvement based on responses to a multi-item index also included in the pretest. As we noted earlier, about half our sample was highly involved (that is, stated that online safety was highly relevant), so splitting the group at the median separated the "safety fanatics" from the rest. This resulted in four groups: High involvement/high self- efficacy (n= 41), low involvement/low self-efficacy (n=38), high involvement/low self efficacy (n=64), and low involvement/high self-efficacy (n=63)

Note: Overall F(8,197) = 23.9, p < 0.001. Treatment x Involvement x Self-efficacy F(7,197) = 2.69, p < 0.02. For the dependent variable
Prevention Intentions (mean = 4.13, standard deviation = 1.39, range = 1–7), an eight-item additive index of prevention intentions assessed on a 7-point scale, with total scores divided by 8.

Experimental results for safety prevention intentions.

Prior to taking the posttest, half the respondents in each of the four groups were randomly selected to visit a Web page with online safety tips from *Consumer Reports*, with the heading "Online Safety is Everyone's Job!" and a brief paragraph arguing that it was the readers' responsibility to protect themselves. That was the personal responsibility treatment condition. The other half of the sample was randomly assigned to a Web page headed "Online Safety isn't My Job!" and arguing that online protection was somebody else's job, not the reader's. That was the *ir*responsibility treatment.

The results are shown in the accompanying figure. The vertical axes indicate average scores on an eight-item index of *preventive* safety behaviors, such as intentions to read privacy policies before downloading software and restricting instant messenger connections. After controlling for pretest scores, the personal responsibility treatment caused increases in online safety intentions in all conditions except one: Those with low self-efficacy and low safety involvement had *lower* safety intentions when told that safety was their personal responsibility than when they were told it was not (the lower line on the graph to the right). Thus, those who are not highly involved in online safety and who are not confident they can protect themselves—a description likely to fit many newer Internet users—were evidently discouraged to learn that safety was their responsibility. The positive effect of the personal responsibility manipulation was greatest in the high involvement, high self-efficacy condition and high involvement users (the left-hand graph) exhibited more protective behavior than users with less involvement (the right-hand graph).

When safety *maintenance* behaviors (for example, updating virus and anti-spyware protections) were examined, the pattern for the low safety involvement group reversed. There, the argument about personal responsibility caused those with high self-efficacy to be *less* likely to engage in routine maintenance than the argument against personal responsibility. We speculate that those who are confident but not highly involved in online safety reacted by resolving to fix the problems after the fact rather than incur the burden of regular maintenance. The other groups had the expected improvements in safety maintenance intentions with the personal responsibility message. However, there was very little difference between treatments for the low involvement/low self-efficacy group perhaps because they felt unable to carry out basic maintenance tasks.

Thus, it is possible to improve safety behavior by emphasizing the user's personal responsibility. However, the strategy can backfire when addressed to those who are perhaps most vulnerable; namely, those who

WE SPECULATE THAT THOSE WHO ARE CONFIDENT BUT NOT HIGHLY INVOLVED IN ONLINE SAFETY REACTED BY *resolving to fix the problems after the fact* RATHER THAN INCUR THE BURDEN OF REGULAR MAINTENANCE.

are uninterested in safety and who lack the self-confidence to implement protection. The personal responsibility message can also backfire when directed to bold (or perhaps, foolhardy) users, those who think they can recover from security breaches but who are not involved enough to apply routine maintenance.

In the present research safety involvement was a measured variable rather than a manipulated one. However, safety involvement might also be manipulated by linking it to a more personally relevant issue, privacy. This is substantiated by the high correlation (0.72) we found between privacy and safety involvement. Privacy is often conceived as a social policy or information management issue [3], but safety threats affect privacy, too, by releasing personal information or by producing unwanted intrusions. Within an organization, the privacy of the firm might be linked to personal involvement through employee evaluation policies that either encourage safe practices or punish safety breaches.

Among all of the factors we have discussed, personal responsibility, self-efficacy, and response efficacy were the ones most related to intentions to engage in safe online behavior in our research [4]. Intentions are directly related to actual behavior. Self-efficacy has a direct impact on behavior over and above their effects on good intentions [2, 5]. Still, there are factors that intervene between intentions and behavior, especially when the protective measures are relatively burdensome and require attention over long periods of time, as is the case for online safety.

Other sources of self-regulation can be tapped. Social norms also affect safety intentions [see 5] if we believe that our spouses and co-workers wish that we would be safer online. Having a personal action plan helps, as does a consistent context for carrying out the safe behavior. That builds habit strength. Another stratagem is offering ourselves incentives for executing our safety plan (for example, a donut break after the daily protection update). That is action control [1], and it has proven effective in managing long-term health risks that are analogous to the network security problem.

Personalized interventions are critical. Seemingly obvious but undifferentiated communication strategies such as alerting users to spyware (found in [2, 5]) could have unwelcome effects. While there are differences by gender and age [5], our experimental data suggests that a more refined audience segmentation approach is required. User education Web sites could screen visitors with "i-safety IQ" quizzes that would route them to appropriate content. Instead of serving as one-shot repositories of safety tips, online interventions might encourage repeat visits to build self-efficacy and maintain action control. User-side applications that detect problem conditions and alert users to their risks and potential protective measures and walk them through implementation would also help.

We conclude that the average user can be induced to take a more active role in online safety. Progress has been made in uncovering the "pressure points" for effective user education. Here, we have attempted to fit these into a logical and consistent framework. Still, much work needs to be done to better understand online safety behavior, including experimental studies that can validate the causes of both safe and unsafe behavior. More diverse populations must also be studied since much of the currently available research has focused either on uncharacteristically naïve [9] or savvy [2] groups. Our experimental findings suggest that relatively modest, if carefully targeted, interventions can be effective in promoting online safety. Thus, improving user responsibility for overall online safety is a desirable and achievable goal. C

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Robert LaRose (larose@msu.edu) is a professor in the Department of Telecommunication, Information Studies, and Media at Michigan State University, East Lansing, MI.
Nora J. Rifon (rifon@msu.edu) is a professor in the Department of Advertising, Public Relations, and Retailing at Michigan State University, East Lansing MI.
Richard Enbody (enbody@cse.msu.edu) is an associate professor in the Department of Computer Science and Engineering at Michigan State University, East Lansing, MI.

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By Frank Safayeni, P. Robert Duimering, Kimberly Zheng, Natalia Derbentseva, Christopher Poile, *and* Bing Ran

REQUIREMENTS ENGINEERING IN NEW PRODUCT DEVELOPMENT

How effective are the socio-technical interactions in developing new products?

What happens when an organization develops a new product? Although a common activity, both academics and practicing product developers have a limited understanding of the process. The process is both technically and socially complex and interacts with the organizational context in unpredictable ways. A basic property of the process is uncertainty [5, 6, 8], which an organization must gradually reduce as it transforms an ambiguous product concept into specific product requirements and ultimately a tangible product that can be launched in the marketplace. What makes new product development (NPD) and the related process of requirements engineering (RE) difficult to manage is that the sources of uncertainty are largely hidden from the view of managers or analysts, embedded in task-related interactions within complex social networks of interdependent organizational roles.

Recommendations for managing NPD and RE uncertainty emphasize cycles of communication among organizational stakeholders [3, 8]. But how effectively do people in different roles communicate when they have conflicting goals and must compete with one

another for scarce organizational resources? And how does the effectiveness of their interactions affect RE and time-to-market for new products? Academics have made little progress modeling and evaluating the effectiveness of such interactions, and product developers often must solve problems by trial and error, which is constrained by the sociopolitical climate of their organizations.

We have been studying and modeling the NPD process in a large multinational high-tech company (MHTC) for the past five years. We have spent hundreds of hours talking to key players involved in NPD and RE, both informally and through formal interviews for data collection. We developed diagnostic methods to help understand the complexity of requirements engineers' social network interactions and to identify significant sources of uncertainty affecting the RE and NPD processes. Here, we examine and report the effectiveness of the interactions and communication patterns between RE and five other organizational roles involved in the NPD process at MHTC.

Study Background

MHTC is a leading Canadian telecommunications firm. To improve its competitiveness, it adopted a strategy of introducing more new products into the market. To be more sensitive to market conditions, responsibility for initiating the NPD process was reassigned from engineering to a restructured marketing unit of the organization called market sponsors (MS).

The company is organized functionally: employees who perform similar functions are grouped into departments, such as operations, sales, marketing, information systems, and so on. Cross-functional communication and coordination difficulties are common in functionally designed organizations not only because each department has its own goals but also because each tends to speak its own specialized language. The collaboration required for NPD success made these communication and coordination problems much more apparent to management. For example, efforts to move new product ideas from marketing through the rest of the organization encountered major difficulties with the new NPD RE process. The problem was information incongruence: requirements engineers demanded a level of technical detail that market sponsors could not provide.

To address these communication and coordination problems, MHTC established another organizational role called feasibility analyst (FA). The task of the FA was to conduct a feasibility study in which the marketing department's new product requirements were mapped onto the firm's existing technical capabilities to determine whether or not the new product could be built and supported at a reasonable cost. Management used the FA's report to decide whether or not to commit company resources to develop the new product. Approved NPD projects were assigned a project manager (PM) whose task was to manage the product development process by setting up and coordinating teams from different functional groups, including an external software development (SD) vendor. Finally, all these roles collaborated with people in the operations (OP) department, which took responsibility for managing product operations following a new product launch.

CROSS-FUNCTIONAL COMMUNICATION AND COORDINATION DIFFICULTIES ARE COMMON IN FUNCTIONALLY DESIGNED ORGANIZATIONS NOT ONLY BECAUSE EACH DEPARTMENT HAS ITS OWN GOALS BUT ALSO BECAUSE EACH TENDS TO SPEAK ITS OWN SPECIALIZED LANGUAGE.

Method

We investigated the effectiveness of social network interactions and communication patterns between requirement engineers and other organizational roles at MHTC using a semi-structured interview methodology adapted from the "echo" method of Bavelas [2, 4, 9]. Interviews began by asking participants to describe their work situation in general terms and to identify other individuals or groups in the organization with whom they interacted on the job. As a result, a diagram in the shape of a star was formed for each interview, with the participant in the middle surrounded by other nodes representing individuals or groups comprising the participant's immediate task-related social network. The participant was then asked to provide concrete examples of behaviors performed by other groups that were helpful from the participant's point of view, and exam-

ples of behaviors that were not helpful. By asking for behavioral examples, the method is designed to focus participants' attention on aspects of the work situation that are meaningful in relation to their own task objectives rather than from the perspective of an external observer.

Twenty-nine individuals were interviewed, representing the five roles identified here (approximately six per role): requirements engineering (RE), project managers (PM), market sponsors (MS), feasibility analysts (FA), and operations (OP). Interviews ranging from two to three hours were recorded and transcribed for coding. Responses were coded collaboratively by the research team members through an iterative process of coding, discussion, and recoding using the QSR N6 [7] qualitative data analysis software. The coding focused on identifying the major categories of helpful and unhelpful behaviors mentioned by interviewees for each role. From these behavior categories, we were able to identify specific patterns of interactions within each working relationship and to evaluate the effectiveness of each working relationship from the perspective of both parties involved.

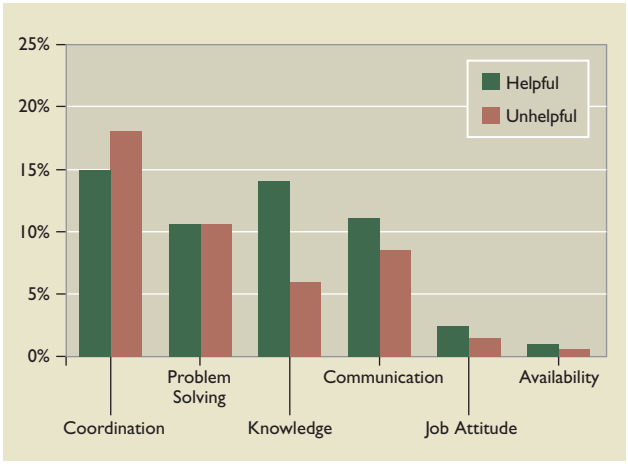

Figure 1. Requirements engineering's helpful and unhelpful behaviors as perceived by other roles.

Results

Strengths and Weaknesses of Each Role. Figure 1 summarizes the main categories of helpful and unhelpful behaviors of RE as identified by the other roles. In total, 201 helpful and unhelpful examples were identified. The percentage of comments in a category reflects its relative importance. Coordination was seen as the most important behavior and availability as the least important. Problem solving and knowledge were of equal importance, followed by communication, and job attitude.

The difference between the percentage of helpful and unhelpful behaviors in a category gives an indication of the relative effectiveness of RE's performance in that category. RE's major strength was knowledge, followed by communication, job attitude, and availability. Their major weakness was coordination. The percentages of helpful and unhelpful comments about problem solving were equal, indicating this was neither a particular weakness nor a strength.

Figure 2 summarizes the main categories of helpful and unhelpful behaviors of other roles as identified by RE. In total, 183 examples of behaviors were identified. The most important category was knowledge, followed by communication, coordination, and problem solving. The least important categories were job attitude and availability. The percentage of unhelpful behaviors was greater than that of helpful behaviors for all six categories, indicating that RE perceived other roles as relatively weak in all areas. The major weaknesses were in communication and coordination, followed by knowledge and problem solving.

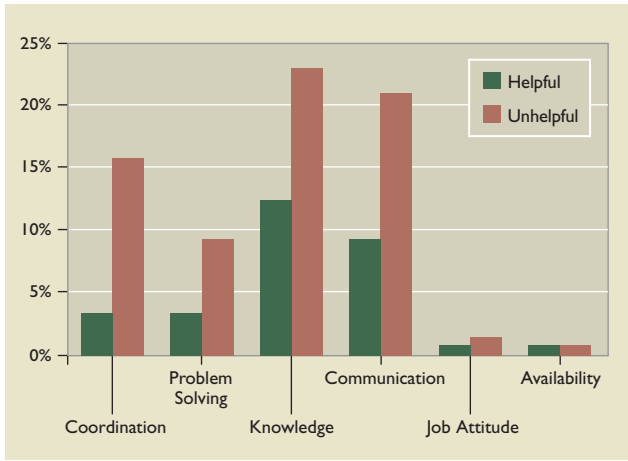

Figure 2. Other roles' helpful and unhelpful behaviors as perceived by requirements engineering.

One striking difference between the two figures is the asymmetry in perceptions between RE and other roles. Requirements engineering was perceived by others as strong in all categories except for a slight weakness in coordination, whereas RE viewed other roles as weak in all categories. One possible explanation for this disparity is that the other roles generate uncertainty for RE in the form of ambiguous requirements and view the RE as helpful since it manages this uncertainty. On the other hand, RE expects less uncertainty in the requirements of other roles, but these expectations are seldom met.

Effectiveness of Interactions. The ratio of the number of helpful to unhelpful behaviors provides an indication of the relative interaction effectiveness of a link in the network, when compared between links or

to the organizational norm. In this case, the organizational norm (average) was estimated as 0.95, computed as the ratio of the total number of helpful to unhelpful behaviors for all roles. Figure 3 is a sociotechnical network diagram based on RE's perception of other units and other units' perception of RE. The direction of each arrow indicates a flow of behaviors from one role to the perceiver role, and the thickness of arrows corresponds to the number of behaviors identified for each link. Ratios larger than 0.95 are displayed in green to indicate effectiveness above the organizational norm, and ratios less than 0.95 are displayed in red to indicate below-average effectiveness. Because software developers (SD) were outside vendors we were unable to interview them, thus there is only one arrow from RE's point of view.

Figure 3. Effectiveness of social network interactions between requirements engineering and other roles.

There are a number of items worth noting. First, the range of interaction effectiveness ratios (from 0.13 to 1.67) reflects variability in the relationships between RE and other roles. Second, the least-effective relationship is between RE and market sponsors (MS). One reason is that the MS is often uncertain about new product requirements and is also the source of requirements change during the NPD process, creating additional work for the RE. Meanwhile, RE's demands for precise information for requirements documentation are viewed by MS as frustrating and bureaucratic, since new product requirements are still being conceived and full details are not yet available. Third, the difference between link effectiveness can be used as a measure of the degree of asymmetry in the relationship. For example, the difference between RE and MS is 0.08, which reflects a fairly symmetrical relationship. On the other hand, the difference between project managers (PM) and RE is 0.95, and the difference between feasibility analysts (FA) and RE is 0.92, indicating fairly asymmetrical perceptions within these relationships. One possible explanation for these asymmetries is that other roles in the organization represent uncertainty to RE, while those roles view RE as a knowledgeable problem solver and appreciate RE's efforts.

Dynamics of Interactions. To provide a more detailed picture of what happens as RE interacts with the other roles, specific examples of helpful and unhelpful behaviors are given here. Due to space constraints, only unhelpful behaviors are reported for links with below average (< 0.95) interaction-effectiveness ratios, and only examples of helpful behaviors are given for links with above-average ratios.

Requirements Engineering and Market Sponsors

- MS Unhelpful (RE's view): changing requirements halfway through the project, unrealistic expectations about delivery time, doesn't listen to technical explanations, not proactive, not prioritizing customer requirements, force-fits projects within a budget, lacks trust.
- RE Unhelpful (MS's view): overestimates costs, uses technical jargon, proposes expensive solutions, inflexible.

Requirements Engineering and Project Managers

- PM Unhelpful (RE's view): lacks SAP knowledge, lacks technical knowledge, calls unnecessary status meetings and reports, doesn't understand we work on multiple projects, expects immediate response to their inquiries.
- RE Helpful (PM's view): good teamwork, meets deliverables and deadlines, conscientious of what their client groups look for, good budget and resource management, flexible, access to experts, tracks projects, provides status reports, identifies problems and gives solutions, proactive, technical knowledge and experience, dedicated and available.

Requirements Engineering and Feasibility Analysts

- RE Helpful (FA's view): responds quickly, open to questions, knowledgeable in their area, suggests solutions, gives realistic expectations of a product, good relationship with operations (OP), accountable and dependable.
- FA Unhelpful (RE's view): offers solutions without knowledge and expertise, insufficient information about new product at meetings, lacks experience, creates patchwork solution, solves the wrong problem, lacks training, mixes up business and product requirements, documents give sales pitch instead of technical requirements, goes directly to OP and bypasses us.

Requirements Engineering and Operations

- RE Helpful (OP's view): looks at different components, such as networks and maintenance, provides good insight on business direction, good technical knowledge and system solutions, good relationship, knows our communication processes, helps us with technology issues, knows customer perspective and company perspective, clarifies processes and steps, helps write methods and procedures, involves us early in the project, gets input from subject-matter experts.
- OP Unhelpful (RE's view): changes product or technology without informing us, slow response on signoff, unavailable when needed, lacks big picture, engages MS without our consent, changes solutions and dates, gives FA solutions based on minimal knowledge, doesn't solve low-level problems before coming to us.

Requirements Engineering and Software Developers

- SD Helpful (RE's view): builds good code, educates others, good links to analysts, proactive, flexible, willing to adjust priorities, works as part of our team, integrates with our people, after-hours support, provides good information, good communication and relationship, complete and accurate estimates, clarifies when we don't understand the questions.

Improving Social Network Interactions

The results provide insights into the behavioral characteristics and effectiveness of socio-technical networks involved in RE and new product development at MHTC. As such, the results establish a base from which to develop strategies for changing network interactions to improve RE and NPD performance. Since many MHTC's interaction difficulties were the outcome of its functionally designed organization structure, one potential way to improve interactions would be to restructure the organization. For example, changing to a product- or market-based design would group REs together with other interdependent roles. A matrix structure could also provide better cross-functional communication and coordination. However, it has been our experience that attempts to redesign large organizations face substantial opposition from major stakeholders. Thus, the recommendations proposed here emphasize more localized strategies that can be implemented within the existing organization structure.

Reduce the Frequency of Unhelpful Behaviors. We found unhelpful behaviors created more work for individuals and delayed NPD projects anywhere from one day to three months. To improve interaction effectiveness between two roles, either the sender role must reduce its unhelpful behaviors or the recipient role must increase its capability to handle the uncertainty associated with unhelpful behaviors [1].

The results indicate that market sponsors were a major source of uncertainty in NPD, engaging in behaviors like "changing requirements" that requirement engineers considered to be unhelpful. One way of reducing the frequency of this behavior would be to involve the RE during the early "ideation" stage of NPD. However, the cost accounting system at MHTC discouraged such early interactions since it required that an RE's time be charged against NPD project funding, which was only available after the project had been approved for feasibility analysis. At least two solutions are available to solve the problem. First, recognizing its importance to project success, higher management in the MS unit could allocate a fund for early RE-MS interactions. Second, REs could provide early project advice free of charge, with costs allocated as overhead to all projects.

OUR FINDINGS PAVE THE WAY FOR THE CONTINUOUS IMPROVEMENT OF SOCIAL-NETWORK INTERACTIONS BY INCREASING THE FREQUENCY OF HELPFUL BEHAVIORS AND REDUCING THE FREQUENCY OF UNHELPFUL BEHAVIORS.

Increase the Frequency of Helpful Behaviors. The results also indicate that REs played a major role in handling NPD uncertainty by sharing their knowledge, which other roles regarded as very helpful. A notable difference between experienced and inexperienced REs was that experienced REs had better knowledge of the organization, of MHTC technical systems, and of who to contact to obtain specific information. Sharing this knowledge with less experienced REs would therefore increase the latter's uncer-

tainty-handling capability. One way to do so would be to set up a knowledge center staffed by experienced REs available to answer questions from REs with less experience or to connect them to another person able to provide the necessary information.

A Cycle of Continuous Improvement. The effectiveness of link interactions was measured in comparison to the overall norm of helpful and not helpful behaviors in the organization. The ratio of 0.95 means there was approximately one unhelpful behavior for every helpful behavior. Needless to say, an organization interested in improving its performance could increase its standards for evaluating interaction effectiveness. For example, if MHTC used a standard of three helpful behaviors for every two unhelpful behaviors (a ratio of 1.5), three of the four effective links in Figure 3 would be reclassified as ineffective. A cycle of continuous improvement can be established in which link-interaction effectiveness is improved, standards are raised, and the process repeated. Statistical techniques for tracking variation in system performance (for example, six sigma methods) could conceivably be applied at the levels of specific behavior categories, link interactions, or the overall socio-technical network.

Conclusion

This study used a socio-technical methodology to measure the effectiveness of interactions between requirements engineering and other groups involved in the NPD process at MHTC. We identified major strengths and weaknesses in the process and specific behaviors that helped and hindered NPD performance. We provided an overall assessment of interaction effectiveness from the point of view of each participant. Our findings pave the way for the continuous improvement of social-network interactions by increasing the frequency of helpful behaviors and reducing the frequency of unhelpful behaviors.

The methodology can be generalized and applied as a diagnostic tool to assess interaction effectiveness in other organizational settings. It enables managers and analysts to obtain a descriptive model of the behavioral characteristics of a complex socio-technical process, providing insights into the sources of task-related uncertainty and a base from which improvement strategies can be devised. The method focuses on social-network interactions among organizational roles and uses a generic style of questioning that does not presume the existence of particular procedures or practices. It is important to recognize that the method provides both a local context-specific view of behaviors, as well as a system-level perspective of the organizational process. By focusing on interaction networks the method reflects role expectations and other organizational constraints that influence task performance (such as division of work, performance measurement, power relationships, and so forth). It is also important to recognize that the method is both quantitative and qualitative in nature. Qualitative results provide rich context-specific information about individual jobs, while the quantitative analysis provides a systemic view of interactions and their effectiveness using a common baseline for comparison. C

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Frank Safayeni (fsafayeni@uwaterloo.ca) is a professor in the Department of Management Sciences, University of Waterloo, Canada.

P. Robert Duimering (rduimering@uwaterloo.ca) is an assistant professor in the Department of Management Sciences, University of Waterloo, Canada.

Kimberley Zheng (jkim08@yahoo.com) is a partner in Group Kinetics Consulting in Vancouver, British Columbia, Canada.

Natalia Derbentseva (natalia@laptev.com) is a postdoctoral student in the Department of Management Sciences, University of Waterloo, Canada.

Christopher Poile (cpoile@uwaterloo.ca) is a Ph.D. candidate in the Department of Management Sciences, University of Waterloo, Canada.

Bing Ran (bingran@psu.edu) is an assistant professor the School of Public Affairs, Penn State University at Harrisburg, Middletown, PA.

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PEER-BASED COMPUTER-SUPPORTED KNOWLEDGE REFINEMENT

AN EMPIRICAL INVESTIGATION

Nonexpert peer-based knowledge refinement, it turns out, is just as helpful as expert-centric knowledge refinement for improving the quality of results.

BY KWANGSU CHO, TINGTING RACHEL CHUNG, WILLIAM R. KING, AND CHRISTIAN SCHUNN

Knowledge management (KM) repository-based systems (such as those involving "best practices" and "lessons learned" applications) are generally costly to operate since they require expert judgment to determine which knowledge submissions are to be included in the system and refined to make them as efficacious as possible.

Empirical evidence in cognitive psychology suggests that experts may not be needed for such refinement when the knowledge consumers are nonexperts. The knowledge "distance" between experts and nonexperts may indeed weaken expert-centric knowledge refinement. In addition, peer judgments delivered to nonexpert end users may substitute well for expert judgments. Multiple peer judgments, especially when provided through computer-supported knowledge-refinement systems, may be much less costly and just as good or perhaps even better than expert judgments, since peers are likely to think more like nonexpert users.

A computer-support system is helpful for facilitating peer-based knowledge refinement, since more peers than experts are probably required for peer-based refinement

THE PROBABILITY OF A SERIOUS PROBLEM BEING DETECTED INCREASES AS THE NUMBER OF PEER REVIEWERS GROWS.

to be effective. Here, we present the results of an experimental study we conducted and a corporate application that confirm our hypothesized equality or superiority of peer-based knowledge refinement compared to expert-centric knowledge refinement. We make no attempt to compare the actual costs of using individual experts vs. multiple peers; we address only the issue of comparing the quality of the results of the two options.

Knowledge repositories are KM systems that play a crucial role in extending organizational memory, preventing organizational forgetfulness, and leveraging competitive advantage. When an organization solicits knowledge from its employees, it must evaluate the submitted knowledge and refine it into a form that is most useful for system users. A traditional assumption in the knowledge-refinement process suggests that experts "provide a framework for evaluation and incorporating new experiences and information" [5].

However, when the users of a repository-based KM system are nonexperts, the knowledge selected and refined by experts may not necessarily be most relevant or useful to those users. For example, technical-support staff members usually access knowledge-repository systems for topics that are unfamiliar to them. And scientists and engineers working on radical innovations often search beyond their own domain expertise for reusable ideas. They may be experts in their own domains but are nonexperts when searching for and evaluating knowledge created in other domains.

Research in cognitive psychology suggests that experts and nonexperts are fundamentally different in the way they represent knowledge and solve problems [3]. Experts have plentiful domain-specific knowledge that is highly organized, while nonexperts have loosely organized knowledge. Compared to nonexperts, experts are quicker at detecting problems; they need fewer cues, access their memory rather than focus on the task at hand, use heuristics rather than exhaustive search, recognize data patterns, and use compiled rules and response plans.

Paradoxically, experts may also have "spectacularly narrow" views on knowledge (from the nonexpert user's point of view). For instance, a study [1] showed that in reading and evaluating requirements documents, better results are achieved when software developers are able to first explore and absorb the perspectives of others (such as testers and users), in addition to their own.

One well-known expert behavior is the way experts tend to underestimate the difficulty of tasks to be performed by nonexperts. Laboratory experiments have shown that people who know a solution to a problem tend to underestimate the difficulty others face in solving it. Similarly, researchers have found that readers with extensive topic knowledge have trouble estimating how well readers with limited topic knowledge will understand the same topic.

Experts also tend to overestimate the potential performance of nonexperts, probably because they detect and diagnose problems on the basis of knowledge readily available in their memories. Experts were shown in [8] to overestimate nonexperts' performance by underestimating the time the nonexperts needed for task completion.

Peer-Based Knowledge Evaluation

When nonexperts code their knowledge into a form that is later refined by an expert, their knowledge differences may prevent them from comprehending the results, even when the refinement is of high quality. Since experts often anchor the knowledge-refinement process to knowledge that nonexperts may not be able to access, such feedback often leads to misunderstanding by nonexpert users. Moreover, explanations that are helpful to experts may not necessarily be helpful to nonexperts.

Contrary to intuition, similarities among peers can actually facilitate knowledge refinement. When the intended audience consists of nonexperts, a group of peers is often better than experts in providing evalua-

tions and feedback on peer-developed materials. Peers are more likely to share knowledgebases, experience, and problems; such socially shared cognition enables them to establish common ground that stimulates development of mutual knowledge, along with an error-correction mechanism. Because peers are closer to one another cognitively and behaviorally, they better understand what they need in a codified piece of knowledge than do experts.

The apparent superiority of peers is presumably due to nonexperts being better at detecting or diagnosing problems that are relevant to their peers. They are more accurate than experts at understanding other nonexperts' problems because they use more cues and more exhaustive search strategies and do not restrict themselves exclusively to private knowledge. These qualities are likely to make nonexperts more adept at coaching their peers in problem solving.

Peer benefits are augmented through the interaction of multiple peers. The value of multiple peers was recognized in [10], observing that large groups of average people can make better decisions than those made by a single expert when they contribute diverse unbiased opinions. When multiple peers participate in knowledge refinement, the aggregated benefits can be significant. One possible reason is that multiple peers create a larger search space for potential problems in the target knowledge; more reviewers find more problems. Also, multiple peers can make a serious problem in the material more salient for the contributor. The probability of a serious problem being detected increases with the number of peer reviewers. When more than one reviewer points out the same problem, the contributor has more reason to take the comment seriously. Moreover, multiple peers counterbalance idiosyncratic biases from individual reviewers, making the refinement process even more reliable.

Peer-Based Refinement System

Here, we describe peer-based knowledge refinement supported by a system described in [4]. Because knowledge is usually submitted in the form of a document, the system facilitates the processing of documents (such as those submitted to best-practice repositories). First, knowledge needs are solicited and potential contributors asked to submit knowledge in, say, the form of proposed "best practices" they have developed for a particular procedure, method, or problem. The first drafts authors submit to the system serve as raw material for the refinement process; the system identifies a diverse set of nonexpert peers to serve as reviewers for each submitted draft. The contributors' identities need not be revealed.

Peer reviewers make qualitative, then quantitative assessments of each submission on the basis of multiple criteria; for this study, the reviewers used flow, logic, and insight as the criteria. They submitted written comments on each of the dimensions. They also rated the quality of each draft on a seven-point scale, with 0 the lowest and seven the highest. After the system collected all evaluations from the reviewers, the system integrated them and computed quality measures for each knowledge submission, as well as the reliability of the individual reviewer evaluations based on built-in reliability-estimation algorithms. At this point, drafts were "stamped" with these initial quality measures based on aggregated ratings (weighted by the computed reliability). The system provided authors with reviewer comments, as well as quantitative quality measures, based on which submitters revised and resubmitted the knowledge document. Each contributor was also able to evaluate the helpfulness of each reviewer's feedback in terms of refining the document.

During the final stage, reviewers from the first-round review process read the revised drafts and generated another round of written comments and ratings the system again used to compute quality measures for the final drafts and reviews. In addition to evaluating the documents, the reviewers determined whether they qualified for inclusion in the repository. Again, contributors assessed the usefulness of these second-round reviews. Synthesizing reviewer recommendations, two rounds of reviews, and contributor evaluation of review quality, the system selected the most valuable documents to be stored in the repository in which contributors and reviewer identities are revealed, recognizing their contribution.

Experimental Study

Our empirical study, conducted at the University of Pittsburgh, simulated the knowledge-refinement process in an experiment that allowed us to observe the relative impact of experts vs. peers on the quality of codified knowledge intended for use by nonexperts. We compared quality improvement in technical reports refined by feedback from a subject-matter expert, a nonexpert peer, or multiple nonexpert peers. The subject-matter expert was an academic scholar with a Ph.D. and social-science expertise. The nonexpert participants were 28 undergraduate students with an average of 3.4 college years enrolled in a social science course not taught by the expert but covering a portion of the expert's domain knowledge.

Individual participants wrote and revised drafts that partially fulfilled the requirements of the course.

The same participants, serving as reviewers and refiners, evaluated six peers' first and revised drafts. Prior to the experiment, participants were tested on basic document-generation skills. Based on the scores, they were matched into blocks, then randomly assigned to one of three feedback source conditions: single expert (SE), single peer (SP), and multiple peers (MP). In the SE condition, the author received only the expert's review. In the SP condition, the best review of the six nonexpert reviews was selected and made available to the author. And in the MP condition, participants received all six peer reviews but not the expert review. To minimize bias, the participants were blind to reviewer identities and status, whether their documents were evaluated by nonexpert peers or by an expert, contributor identity, and who could receive reviewer feedback. The participants were all told that the anonymous reviewers alone would determine the quality of their submitted documents.

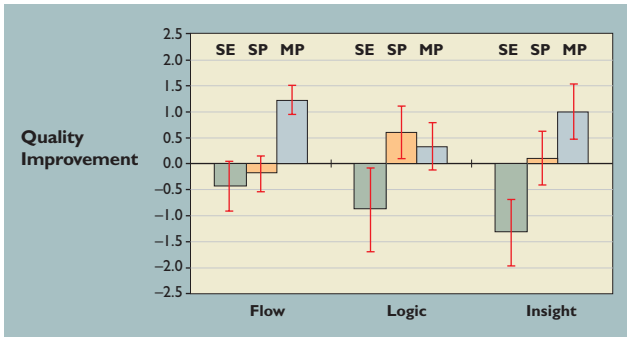

Figure 1. Quality improvement with standard error bars.

About three months after the experiment, the expert reevaluated 30% of the same documents (randomly selected). There was significant agreement between the expert's first and second evaluations, showing strong test-retest reliability. A second expert then independently evaluated the expert and nonexpert evaluations while being blind to the source of evaluations and showed a statistically significant correlation with the expert.

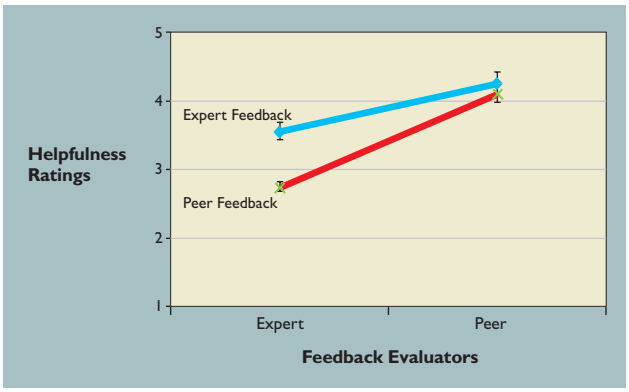

Figure 2. Expert and peer perception of expert and peer feedback.

After being assigned to experimental "treatments," the course instructors introduced the participants to the system. All remaining procedures were managed online by the system. On the system's prompt, all participants submitted their first drafts online by the same date. Each participant then received six drafts (randomly selected by the system). At the same time, the expert reviewed all the drafts. The expert and nonexpert reviewers assessed the drafts on the three evaluation dimensions: flow (document readability, emphasizing organization and overall composition); logic (the degree to which the arguments presented in the document were supported by evidence); and insight (whether the document provided innovative ideas that indicate creativity).

Even though each document received one expert and six peer reviews, only some of the reviews were made available to each of the contributors, depending on the experimental condition. After receiving feedback, each participant submitted revised drafts, evaluated the helpfulness of the feedback, then received the second reviews on the revised drafts. Contributor evaluations of these reviews were not available to the reviewers.

Results of the Experiment

We assessed the differences in the impact of expert-based vs. peer-based knowledge refinement through a two-way mixed ANOVA on quality improvement from first to second drafts as measured by expert evaluations. Simple main-effect analyses revealed that flow in MP was significantly better than in SE and SP, that logic was the same across all conditions, and that insight in MP was significantly better than in SE (see Figure 1). Documents reviewed by multiple peers undergo significant quality improvement in both flow and insight. This result supports our hypothesis that knowledge distance between experts and nonexperts may hinder knowledge refinement and our hypothesis that knowledge refinement benefits from multiple peer feedback. The effect was particularly strong on the insight criterion, suggesting that multiple peer reviews are likely to stimulate creative ideas. In addition, peers judged expert and peer feedback as equally helpful, while experts judged expert feedback as more helpful than peer feedback, suggesting that when the target audience consists of nonexpert users, nonexpert refiners are just as helpful as expert evaluators (see Figure 2).

WHEN THE TARGET AUDIENCE CONSISTS OF NONEXPERT USERS, NONEXPERT REFINERS ARE JUST AS HELPFUL AS EXPERT EVALUATORS.

Real-World Application

We verified these experimental findings with data we collected from an IT consulting firm in Korea that had implemented a procedure enabling peer-expert comparisons in its customer service process. It asked customers to evaluate answers ("thumbs up/satisfactory" or "thumbs down/unsatisfactory") provided by customer service representatives. Answers to customer questions in an existing database were provided by either expert designers or programmers. Out of 245 answers, 134 (55%) were refined by peers, and 111 (45%) were refined by experts before customers received responses. Among the 162 (66%) rated by customers, 116 (71%) were voted satisfactory and 28 (46%) unsatisfactory. Meanwhile, 79% of the peer-refined responses were satisfactory, and only 62% of the expert-refined responses were satisfactory (see Figure 3). In contrast, 21% of the peer-refined responses were unsatisfactory, whereas 38% of the expert-refined responses were unsatisfactory. These differences are statistically significant, giving further credibility to the generalizability of the results of our experiment.

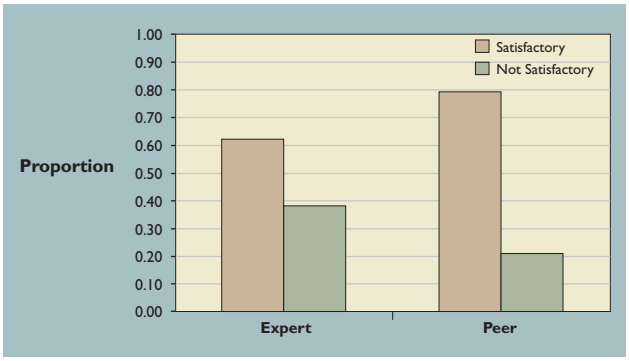

Figure 3. Customer satisfaction ratings of answers refined by experts and by peers.

Results

Our study represents one of the first attempts to empirically investigate properties of the knowledge-refinement process. The results show that, as we hypothesized, the knowledge "distance" between experts and nonexperts impaired expert-based knowledge-refinement, while the close knowledge distance among peers facilitated knowledge refinement.

Considering that the work of experts is rarely done without time constraints, expert-based knowledge refinement may be worse. Experts under time pressure often default to such typical expert behaviors as using fewer cues than nonexperts to build task representations. They exhibit these behaviors by activating existing task schemata in memory. By relying more on their expert instincts under time pressure, experts may be less likely to take the time to consider the nonexpert's perspective.

Computer-supported peer review systems offer what may be a more financially affordable option. Contributors and reviewers alike may be rewarded for their service by publishing their names when their knowledge is selected for inclusion in a repository. Thus, contributors and reviewers alike enjoy substantial social rewards (such as citation credit and peer approval). This was observed in an informal knowledge repository in a software development firm [6] and is a well-known characteristic of the Linux virtual development team [9]. Over time, such repositories enable development of reputation systems, helping users assess likely knowledge relevance and quality. A similar reputation system at the group level has directed user attention to high-quality content in an electronic document database [7].

A peer-based knowledge-refinement process designed to help users assess content quality should gradually build trust as a result of the creation of a virtual community. When a large number of documents is available in such a repository, the system becomes a knowledge market that competes for the reader's limited attention [7]. Systems allowing users to inspect feedback from other users may help maintain trust in the repository in a way that's similar to the way online merchants (such as Amazon.com and eBay.com) establish consumer trust through a peer-feedback mechanism.

Peer-based knowledge refinement makes it possible for organizations to establish reward systems for both

knowledge codification and refinement. Such systems may use extrinsic incentives, as well as social reputation rewards, to motivate employees to participate in knowledge refinement. Employees rewarded through this process may be more likely to use knowledge from the repository system for their own tasks. These benefits may explain the success of peer reviews (such as software pattern writers relying on peer discussions when writing up patterns). C

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Kwangsu Cho (kwangsu.cho@gmail.com) is an assistant professor in the School of Information Science and Learning Technologies at the University of Missouri, Columbia.

Tingting Rachel Chung (ting@pitt.edu) is a Ph.D. candidate in the Katz Graduate School of Business of the University of Pittsburgh, Pittsburgh, PA.

William R. King (billking@katz.pitt.edu) is a University Professor in the Katz Graduate School of Business of the University of Pittsburgh, Pittsburgh, PA.

Christian Schunn (schunn@pitt.edu) is an associate professor in the Learning Research and Development Center of the University of Pittsburgh, Pittsburgh, PA.

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Dinesh K. Gauri, Amit Bhatnagar, and Raghav Rao

Role of Word of Mouth in Online Store Loyalty

Comparing online store ratings with other e-store loyalty factors.

In the e-commerce realm, most price comparison Web sites such as pricegrabber.com and cnet.com also provide information regarding store ratings to their customers. These e-ratings are obtained from previous customers and are a credible source of information for current customers in the pre-purchase phase. However, it is not clear how important these ratings are to consumers as compared to other store attributes, such as site design, clarity of information, order tracking, on-time delivery, and customer service. Store managers responsible for allocating resources across different attributes need to know this in order to provide value to the customers visiting their site.

In traditional marketing, word of mouth (WOM) is the information one obtains through interpersonal communication with friends and family but in an online environment, store ratings are the source of this interpersonal communication and are obtained from other consumers, not just friends and family. WOM has been studied extensively in traditional marketing [3] and MIS [4]. The MIS literature [1, 5, 6] has focused on building trust in the online environment to alleviate any risks associated with shopping online. Bowman and Narayandas measured WOM via a survey, and found WOM increases customer loyalty [3]. In the study reported here, we compare online store ratings with other determinants of e-store loyalty. We are also interested in learning how ratings influence online store loyalty across product categories.

Data

The data was collected from BizRate.com, an online price comparison Web site, and Alexa.com. Online shoppers use BizRate.com to compare prices of an item across multiple online retailers. For each retailer, in addition to prices, Bizrate.com also provides information about aggregate customer ratings on a number of attributes. BizRate.com obtains the data for these customer ratings from two different sources. The first source is e-tailers that have allowed BizRate to collect feedback directly from their customers. The second source is a panel of over 1.3 million active online shoppers who have volunteered to rate online stores. BizRate.com determines the weighted averages of the customer ratings across the two sources, and these aggregate ratings for each store are displayed on the Web site.

After customers conclude a purchase, they are requested to complete a feedback form. Bizrate.com also conducts a follow-up email survey to obtain customer feedback regarding quality

of post-purchase services. Across the two surveys, the respondents are asked to rate the retailers on 14 e-store attributes as shown in the table here. The respondents must also provide an overall rating for each store, which is used by BizRate.com to determine the percentage of positive ratings for each store. This variable allows us to determine how the positive reviews provided by other consumers influence a consumer. For each retailer, BizRate.com also provides information about the total number of customers that have reviewed that store. The respondents are also asked to state the likelihood of their shopping again at that store on a scale of 1 to 10. Consumer responses to this question became the dependent variable in our analysis.

Factors	Books and Magazines	DVD and Video	Flowers and Food
Relative Price	0.02	0.04	0.04
Ease of Finding	0.05	0.06	0.06
Selection	0.09	0.09	0.09
Clarity	0.13	0.07	0.07
Overall Look/Design	0.07	0.01	0.01
Shipping Charges	0.005	0.06	0.06
Variety of Shipping	0.04	0.06	0.02
Charge Statement	0.02	0.03	0.03
Number of Reviews	0.007	0.008	0.002
Years on the Web	0.005	0.003	0.005
Met Expectations	0.13	0.15	0.16
Product Availability	0.12	0.13	0.17
Order Tracking	0.13	0.13	0.15
On-time Delivery	0.19	0.16	0.17
Percentage of Positive Ratings (Positive WOM)	**0.25**	**0.24**	**0.22**

Note: The values in each of the cell represent the average contribution of the corresponding variable in predicting the repurchase likelihood at the e-store.

Average contribution of a variable in predicting repurchase likelihood across categories using dominance analysis.

We collected data for 441 online retailers during late 2005.[1] One of the goals of this study was to determine whether the importance of store ratings would vary with product category. We collected data for retailers of three different product categories, such that two (DVDs and Videos, Books and Magazines) were standard and had very little variance in features and quality, and the third (Flowers and Food) was non-standard and therefore had high variance in features and quality.

Analysis

We sought to determine the importance of different store attributes in influencing the likelihood of repurchase. The simplest approach would be to conduct a linear regression analysis with the repurchase intention as the dependent variable and the stores' attributes as the independent variables, and then compare the standard coefficients. Unfortunately, all the independent variables are highly correlated, leading to the problem of multicollinearity.[2] The common solution to the multicollinearity problem is to factor the independent variables into orthogonal factors. This approach meant that rather than studying the importance of store ratings, we would be able to study the importance of some factor made up of more than one store attribute.

We used dominance analysis [2] to compare the relative importance of different predictor variables. In dominance analysis (DA), the overall contribution of an independent variable to the prediction of the dependent variable (repurchase intention in our case) in a multiple regression is determined by considering all possible subset selections of various models possible with the set of independent variables. One variable is said to dominate another if it is more useful than its competitors in all subset regressions. The DA approach provides the most general context by taking into account all relevant subset models, where a relevant model is either any subset model that can be formed from the predictors or any subset model that is theoretically possible and of interest. The average contribution of each variable in the various categories, computed after running the DA approach is reported in the table here. If this average contribution is high for any independent variable, it will imply that particular variable contributes more

[1] See www.bizrate.com for a complete list and description of these attributes.

[2] To check for multicollinearity, we used variance inflation factors (VIF), which are the diagonal elements of the inverse correlation matrix. We found the VIF values of a few variables were above 10, showing there was a multicollinearity problem.

It is interesting that of all the attributes, positive customer reviews have the greatest impact on repurchase intention.

toward predicting the repurchase intentions of consumers in that category.

We find a similar pattern of importance rankings across all the three categories. We find that positive word of mouth has the maximum impact on repurchase intention in all the cases. This is followed by on-time delivery and order tracking, suggesting the relative importance of different store attributes is not influenced by product category.

Conclusion

It is interesting that of all the attributes, positive customer reviews have the greatest impact on repurchase intention. This is consistent across all categories. Even more impressive is the finding that number of years on the Web has the least impact on repurchase intention. This has significant implications for managers of online stores because it suggests that stores would attract more customers by having positive customer reviews. The amount of time the store has been in business does not seem to affect the repurchase intention of consumers. Another interesting finding is that it is not the total number of reviews that influences customer repurchase intention, but the percentage of positive reviews. This is important for new retailers that will have a lower number of total customer reviews than well-established retailers.

Our findings suggest managers can increase loyalty to their price comparison sites by providing customer review ratings. Interestingly, while most of the price comparison sites have started offering these ratings, many of them do not. A case in point is Froogle, Google's price comparison Web site, which does not provide customer ratings of stores. Froogle has not become widely used and we suspect one reason is because the site does not provide store ratings.[3]

Our finding may also explain paradoxes like Amazon.com having higher prices than Half.com and still performing better. The difference is that Amazon.com has customer reviews and Half.com does not. The chief executive and founder of Amazon, Jeffrey P. Bezos, also acknowledged this: "Word of mouth remains the most powerful customer acquisition tool we have, and we are grateful for the trust our customers have placed in us. Repeat purchases and word of mouth have combined to make Amazon.com the market leader in online bookselling." C

[3]According to Nielsen/NetRatings, Froogle had 6.6 million visitors in July 2006, lagging behind Shopzilla.com, the top shopping search engine, which racked up 17.2 million visitors, and Yahoo's shopping network, which had approximately 11.1 million.

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Dinesh K. Gauri (dkgauri@syr.edu) is an assistant professor in the marketing department at the Whitman School of Management, Syracuse University, NY.
Amit Bhatnagar (amit@uwm.edu) is an associate professor with the Department of Marketing at the University of Wisconsin, Milwaukee.
Raghav Rao (mgmtrao@buffalo.edu) is a professor of MIS and adjunct professor of CSE at the State University of New York at Buffalo.

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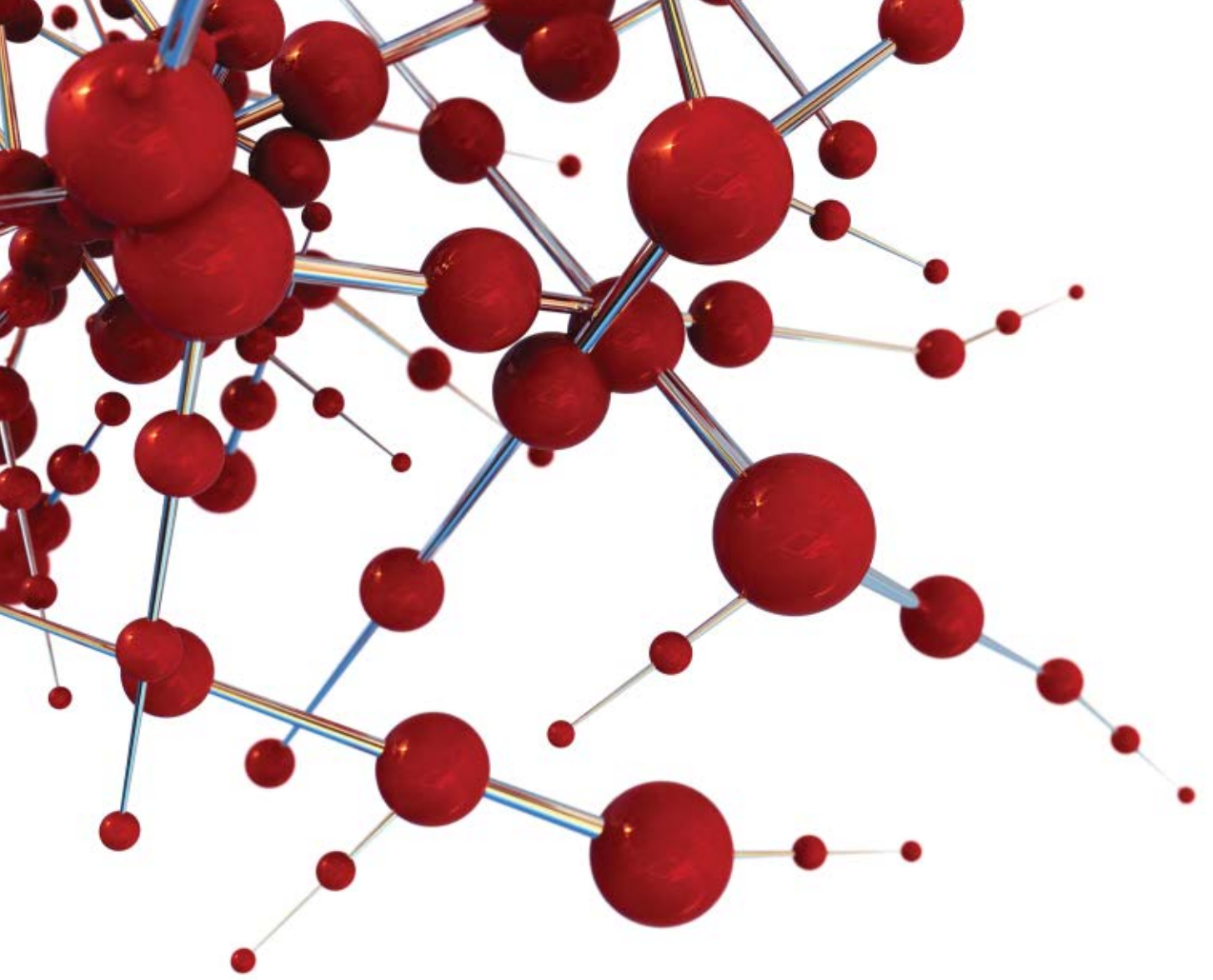

Allegheny College
Department of Computer Science

The Department of Computer Science invites applications for a tenure-track position beginning Fall 2008. Qualifications include a Ph.D. in computer science. Applicants with interests in graphics, media computation, computational science, or data management and security are preferred; however, candidates from other areas of computer science will be considered.

Applicants must provide evidence of ability to teach effectively at the undergraduate level, commitment to liberal arts education, and continuing contribution to the discipline. Responsibilities include teaching and advising undergraduates, guiding students in senior research projects, and contributing to the college-wide freshman/sophomore seminars that emphasize speaking and writing. Salary will be competitive; start-up funds are available. Rank will be commensurate with credentials and experience.

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Send letter of application, vita, statement of teaching and research interests, applicable transcripts, and arrange to have three letters sent from references, at least one of whom can comment on teaching, to: Dr. Robert S. Roos, Associate Professor and Chair, Department of Computer Science, Allegheny College, Meadville, PA 16335; email: robert.roos@allegheny.edu.

Review of applications will begin immediately. Allegheny College is an Equal Opportunity Employer with a strong institutional commitment to develop a diverse faculty and staff. Women and members of other under-represented groups are especially encouraged to apply.

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PAUL WATSON

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Indiana University Purdue University-Indianapolis

Department of Computer and Information Science

The Department of Computer and Information Science invites applications for a tenure track position at the Assistant Professor level, beginning August 2008. Applicants must hold a Ph.D. in Computer Science or closely related field at time of appointment, and are expected to develop a high-quality funded research program and be committed to excellence in teaching undergraduates and graduate students.

Applications are accepted from candidates in all areas of computer science, though we are especially interested in candidates with expertise in the areas of biocomputing, databases and datamining, and network security. The application must consist of a letter of interest, curriculum vitae, and a statement of research direction and teaching interests. Applicants should also arrange for three letters of recommendation to be mailed directly to the Committee.

The department is committed to achieving excellence through diversity. Applications and nominations of women, persons of color, applicants with disabilities, and members of other under-represented groups are desired.

Send the materials to: Faculty Search Committee, Department of Computer and Information Science, IUPUI, 723 W. Michigan Street, SL 280, Indianapolis, IN 46202-5132. E-mail applications may be submitted to wittlief@cs.iupui.edu. Consideration of applications will begin on February 15, 2008 and will continue until the position is filled. IUPUI is an EEO/AA Employer, M/F/D. For further information about the department, please visit http://www.cs.iupui.edu/.

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Lamar University

Department: Computer Science

Contact Person: Lawrence J. Osborne E-Mail Address: cs_search@mail.cs.lamar.edu

Applications are invited for at least one tenure-track position beginning in the summer or fall of 2008. Requirements include a Ph.D. in computer science, strong commitment to teaching, and demonstrated research ability. The normal teaching load is 9 hours per semester, but the load is reduced for new

faculty and those with external funding. Candidates with expertise in database, HCI and graphics, visualization, and high performance computing, Web intelligence, and systems-related areas, but applicants in all areas of computer science will be seriously considered. Rank and salary are commensurate with experience and credentials.

Applications, including curriculum vitae, at least three letters of recommendation, one of which should address teaching qualifications, and a cover letter should be sent to:

Chair, Search Committee
Department of Computer Science
P.O. Box 10056
Lamar University
Beaumont, TX 77710

Applications may be submitted electronically http://dept.lamar.edu/humanresources/facapp.pdf. Review of applications will begin immediately and will continue until the position is filled.

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Lawrence Tech University
Department of Computer Science

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Assistant Professor – Computer Science

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Please send a statement of interests with a detailed curriculum vita with names of three references. Minimum two of the references should comment on teaching ability. Please send to: Dr. Carol M. Hurwitz, Chairperson, Department of Mathematics and Computer Science, Manhattan College, Riverdale, NY 10471 by April 15, 2008.

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Informed by the College's educational mission and guided by the goals and objectives established by the College's strategic plan, the Dean of Library and Information Services Represents LIS to the college's academic community, other service departments, the administration and the local community. Develops organizational models for LIS, sets strategic priorities for addressing library and computing facilities needs and establishes performance goals that incorporate staff development and training.

Recommends budget and allocates resources to meet the needs of the community. Oversees integration and support of sites abroad as well as summer programs and the Monterey Institute of International Studies.

As a member of President's Staff and the Academic Affairs Committee, the Dean contributes to college-wide policy-setting and strategic planning by bringing to these discussions both functional expertise (as Leader of LIS) as well as a broad perspective regarding the liberal arts and higher education. The Dean coordinates and assists a Board of Trustees Technology Committee and serves as a voting member of the faculty.

The ideal candidate will hold a MS in Library/Information Science and/or Computer Science; a Ph.D. is preferred. Strong leadership experience, collaboration and decision-making skills. Proven written and oral communication skills. Extensive management and planning experience, including management of both human and financial resources. In-depth knowledge of scholarly communication, academic library services and information technologies. Broad and thorough knowledge of the academic enterprise. Active support of diversity initiatives, demonstrated ability to recruit, hire, retain and manage a diverse workforce and to promote a diverse work environment through education, training and professional development.

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Mississippi State University

Head

Department of Computer Science and Engineering

Applications and nominations are being sought for the Head of the Department of Computer Science and Engineering (www.cse.msstate.edu) at Mississippi State University. This is a 12-month tenure-track position.

Part of the Bagley College of Engineering, the department has approximately 325 undergraduate majors, 70 graduate students, and 18 tenured and tenure-track faculty. The department offers undergraduate programs in Computer Science and Software Engineering, and jointly administers the undergraduate program in Computer Engineering with the Department of Electrical and Computer Engineering. At the graduate level, we offer M.S. and Ph.D. degrees in Computer Science and faculty also direct graduate students in Computational Engineering and Computer Engineering. Certificates in Software Engineering, Information Assurance, and Computational Biology are also available. Research expenditures total about $3 million dollars annually and the university as a whole is ranked 48th among 271 U.S. institutions in computer science expenditures. Research areas for the department are high-performance computing, artificial intelligence, graphics and visualization, computer security, and software engineering. Three current faculty members have received NSF CAREER awards. Our computer security area has been designated a National Center of Academic Excellence in Information Assurance Education (CAEIAE) by the National Security Agency (NSA).

Mississippi State University is a comprehensive land-grant institution with approximately 17,000 students and about 1,000 faculty members. The university is a leader in high performance computing, housing a supercomputer in the top 20 among U.S. universities. The university's main campus is located in Starkville, Mississippi, a vibrant community approximately 2 hours from Jackson MS, Birmingham AL, and Memphis TN.

The successful Head will provide:

- Vision and leadership for nationally recognized computing education and research programs
- Exceptional academic and administrative skills
- A strong commitment to faculty recruitment and development

Applicants must have a Ph.D. in computer science, software engineering, computer engineering, or a closely related field. The successful candidate must have earned national recognition by a distinguished record of accomplishments in computer-science education and research. Demonstrated administrative experience is desired, as is teaching experience at both the undergraduate and graduate levels. The successful candidate must qualify for the rank of professor.

Please provide a letter of application outlining your experience and vision for this position, a curriculum vita, and names and contact information of at least three professional references. Application materials should be submitted online at

http://www.jobs.msstate.edu/

Screening of candidates will begin February 22, 2008 and will continue until the position is filled. Mississippi State University is an AA/EOE institution. Qualified minorities, women, and people with disabilities are encouraged to apply.

Mississippi State University

Faculty Position in Computational Biology

The Department of Computer Science and Engineering (http://www.cse.msstate.edu) invites applications for a tenure-track faculty position at the Assistant or Associate Professor level in the area of computational biology. Candidates for the position are expected to hold a Ph.D. in computer science, computational biology, or a closely related field (ABDs may be considered). The person filling this position will be affiliated with the MSU Institute for Digital Biology (IDB), a university-level multi-disciplinary research institute that merges MSU's strengths in engineering and biology to solve problems related to health, nutrition, biofuels, food safety, biosecurity and agriculture. IDB faculty are currently funded by NSF, USDA, DOD, NIH, and DOE. MSU has a state-of-the art facility for genomics and proteomics (the Life Science and Biotechnology Institute). Research areas within the department include high performance computing, artificial intelligence, graphics and visualization, computer security, and software engineering.

Mississippi State University is the largest university in the State of Mississippi with approximately 1000 faculty and 17,000 students. The Department of Computer Science and Engineering has 18 tenured and tenure-track faculty and offers academic programs leading to the B.S., M.S. and Ph.D. in Computer Science, and a B.S. in Software Engineering. The department offers a certifi-

cate in Computational Biology and jointly administers the B.S. in Computer Engineering. Faculty also direct Ph.D. students in Computational Engineering and Computer Engineering and work with a number of additional on-campus research centers including the High Performance Computing Collaboratory, the Institute for Neurocognitive Science and Technology, and the Sustainable Energy Center. Seven faculty members in the department have been recognized by NSF CAREER awards. Department research expenditures total around three million dollars per year. Mississippi State University is ranked 48th among 271 U.S. institutions in R&D expenditures in engineering by the National Science Foundation.

Please provide a letter of application, a curriculum vita, research and teaching statements, and names and contact information of at least three professional references. Application materials should be submitted online at http://www.jobs.msstate.edu/, or emailed to office@cse.msstate.edu. Screening of candidates will begin February 28, 2008 and will continue until the position is filled. Mississippi State University is an AA/EOE institution. Qualified minorities, women, and people with disabilities are encouraged to apply.

Missouri University
Department of Computer Science

The Department of Computer Science at the Missouri University of Science and Technology is seeking outstanding applicants for tenure-track faculty positions. The Missouri University of Science and Technology is the primary science and engineering campus of the Missouri University system. Detailed information is available at http://hr.mst.edu/employment/compsci.html. (Formerly University of Missouri-Rolla)

Moravian College
Department of Computer Science

Moravian College invites applications for a one-year position at the assistant professor or instructor level in computer science to begin Fall 2008, with the possibility of a tenure-track position to begin Fall 2009. Preference will be given to applicants with a Ph.D. in computer science, but applicants with a M.S. in computer science will also be considered. Applicants should have a broad range of computer science expertise and interests. The successful candidate will have strong interpersonal skills and a primary commitment to undergraduate teaching and scholarship for computer science in a liberal arts context. Teaching responsibilities will include undergraduate courses for the computer science major as well as courses for non-majors. Moravian College faculty are encouraged to participate in interdisciplinary teaching. Moravian College values diversity and encourages individuals from under-represented groups to apply. Review of applications will begin February 20. Applications should include resume, transcripts, a statement of teaching philosophy, and three letters of recommendation, and should be sent to Kay Somers, Chair, Department of Mathematics and Computer Science, Moravian College, 1200 Main Street, Bethlehem, PA 18018-6650.

Mount Holyoke College
Assistant Professor

Mount Holyoke College has a one-year position for a full-time, visiting assistant professor in any area of specialization. We are seeking someone with a strong interest in teaching and working closely with undergraduate students. Ph.D must be completed by September 2008. Teaching experience is required. The teaching load will comprise two courses per semester. Mount Holyoke is an Affirmative Action, Equal Opportunity Employer. Review of applications will begin January 15 and continue until the position is filled. Candidates should submit CV, research description, and teaching statement online at http://jobsearch.mtholyoke.edu. Arrange for three letters of reference to be sent directly to human-resources@mtholyoke.edu or Mount Holyoke College, 50 College Street, 1 Skinner Hall, South Hadley, MA 01075, attention Computer Science Visitor Search. At least one recommendation letter should address teaching experience.

Purdue University
Tenure Track Positions

Application Software Development and Database Management Systems Purdue University's Department of Computer and Information Technology, College of Technology, invites applications for 2 tenure-track positions beginning in August 2008 in the following areas: Application Software Development: This position's focus is in the area of application software development using contemporary programming languages, development tools and methodologies. Preference will be given to candidates who have teaching experience, publishing experience, an earned doctorate in a related field, and experience developing application software at all levels of the enterprise including desktop, client/server, web, and multi-tier enterprise applications using Java and/or Microsoft.NET technologies and a relational database management system such as Oracle or Microsoft SQL Server.

Database Management Systems: The database position is focused on areas of database design and administration, database programming and advanced database applications. Preferred candidates will have academic and/or industry experience in one or more of the following: enterprise database design, development and management; object-oriented analysis and design; data warehousing and data mining; special purpose databases; and enterprise level database infrastructure.

Please go to http://www.tech.purdue.edu/cit/positions for more information on all available positions.

Purdue University is an Equal Opportunity /Equal Access/Affirmation Action Employer

Seattle University
Chair of Department of Computer Science and Software Engineering

Seattle University invites applications for the position of Chair of the Department of Computer Science and Software Engineering to begin on July 1 of 2008. Applicants are required to have a Ph.D. in Computer Science, Software Engineering, or other closely allied field. Candidates should have experience as a tenured professor, program director, or department chair and be capable of leading a young and dynamic department and teaching a broad range of software engineering and/or computer science courses. Opportunities for industrial collaborations abound in the Seattle area, home to hundreds of software, Internet, and telecommunications companies.

Please visit http://www.seattleu.edu/scieng/comsci/ for more information about the position and how to apply.

Seattle University, founded in 1891, continues a more than four hundred and fifty year tradition of Jesuit Catholic higher education. The University's Jesuit Catholic ideals underscore its commitment to the centrality of teaching, learning and scholarship, of values-based education grounded in the Jesuit and Catholic traditions, of service and social justice, of lifelong learning, and of educating the whole person. Located in the heart of dynamic Seattle, the University enrolls approximately 7,200 undergraduate and graduate students in eight colleges and schools. Students enjoy a university ethos characterized by small classes, individualized faculty attention, a strong sense of community, a commitment to diversity, and an outstanding faculty.

Seattle University is an equal opportunity employer.

Spatial Corp.
Software Engineer

SPATIAL CORP. is a wholly owned company of Dassault Systèmes and the industry leader in the development of open, component-based 3D modeling technology for CAD/CAM/CAE

applications and interoperability solutions. In this position, you will be involved with all stages of the software product life cycle for various C++ software products. You will be a part of a closely-knit team that supports the daily build, test, and release cycle of our products. Because a strong focus of the position is on creating new processes, the ideal candidate will be energetic, creative, and a proficient troubleshooter, yet also not mind the day-to-day activity of monitoring builds and tests. Your responsibilities will include but not be limited to:

- Scheduling and monitoring daily builds and tests
- Maintaining and improving the build and test infrastructure
- Developing and supporting processes required for the software product life cycle

Qualifications:
BS in Computer Science or other engineering degree with computer science emphasis

Required Skills:

- Knowledge of multi-platform environments: Windows, Unix
- Knowledge of a source code control system such as CVS
- C/C++
- Scripting tools: perl, shell batch
- SQL experience, preferably MySQL
- Capacity to switch quickly from one task to another
- Good communication and teamwork skills

Desired Skills:

- 2-3 years professional experience in an Integration or QA group
- Java

Spatial Corp. is an equal opportunity employer with competitive salaries and an excellent benefits package. Please visit our website at http://www.spatial.com/

Technical University Berlin
Professorship Service Centric Networking

Technical University Berlin in cooperation with Deutsche Telekom Laboratories invites applications for a Professorship (W2) for 5 years in "Service Centric Networking". For details see http://www.laboratories.telekom.com/ipws/English/LabsGeneral/Karriere/WissenschaftlicheMitarbeit/Pages/IV-699-Professor.aspx

Technical University Berlin
Professorship Security in Telecommunications

Technical University Berlin in collaboration with Deutsche Telekom Laboratories invites applications for a Tenured Full Professorship (W3) " Security in Telecommunications". For details see http://www.laboratories.telekom.com/ipws/English/LabsGeneral/Karriere/WissenschaftlicheMitarbeit/Pages/IV-542-Professor.aspx

The American University of Afghanistan
Assistant Professor of Information Technology

The American University of Afghanistan is seeking interested candidates for faculty positions in Information Technology. We offer a unique opportunity to teach and work in a newly formed university located in Kabul. Since our first students enrolled in March 2006 the University is growing steadily, enrolling a new group of entering undergraduate students each semester. While the University has offered thus far several introductory IT courses, beginning with the Fall semester of 2008 the IT program will be expanding into a major course of study. The successful applicant will demonstrate a commitment to undergraduate teaching and the ability to engage undergraduates in research and class projects. Teaching responsibilities include participation in our introductory courses as well as upper level courses in the applicant's areas of interest and expertise, including but not limited to computer networks, databases, eCommerce & web development, programming languages, or operating systems. The teaching load per semester is four courses with no more than three course preparations. A Ph.D. or M.Sc. in a computer related area is required for this position. Salary and level of appointment commensurate with experience.Please see our website for descriptions of the faculty position and how to apply: www.auaf.edu.af

The Hong Kong Polytechnic University
Department of Computing

The Department invites applications for Assistant Professors in most areas of Computing, including but not limited to Software Engineering / Biometrics / Digital Entertainment / MIS and Pervasive Computing. Applicants should have a PhD degree in Computing or closely related fields, a strong commitment to excellence in teaching and research as well as a good research publication record. Initial appointment will be made on a fixed-term gratuity-bearing contract. Re-engagement thereafter is subject to mutual agreement. Remuneration package will be highly competitive. Applicants should state their current and expected salary in the application. Please submit your application via email to hrstaff@polyu.edu.hk. Application forms can be downloaded from http://www.polyu.edu.hk/hro/job.htm. Recruitment will continue until the positions are filled. Details of the University's Personal Information Collection Statement for recruitment can be found at http://www.polyu.edu.hk/hro/jobpics.htm.

University at Albany, SUNY
College of Computing and Information (CCI)

The College of Computing and Information (CCI) of the University at Albany, SUNY, invites nominations and applications for up to six new tenure-track faculty positions in its three constituent departments: Computer Science, Informatics, and Information Studies.

We seek a mix of computer scientists, information scientists, social scientists, and researchers in libraries, government, education, and other applicable environments. Candidates will be considered for appointments at all levels and senior positions may have appointments in multiple departments.

Applicants should have a Ph.D. or should have completed his/her Ph.D. by the starting date of appointment. The degree(s) must be from a college or university accredited by a U.S. Department of Education or internationally recognized accrediting organization. Applicants must have strong research credentials. We especially welcome candidates who would work across disciplines and provide linkages between departments. All applicants, regardless of discipline, should have an explicit focus on the construction of effective computing and information systems and/or the use of information in diverse settings. Applicants must include in their application their ability to work with and instruct culturally diverse groups of people. Faculty will participate in all levels of the College's instructional programs, from undergraduate through doctoral education. Priority will be given to applicants with a strong interest in helping develop these programs and the interplay between them.

Details concerning the college's research portfolio and the search for new faculty members are available at http://www.albany.edu/cci/portfolio.shtml

Competitive salary and startup package, commensurate with experience.

For a complete job description, please visit http://albany.interviewexchange.com/joboffer details.jsp?JOBID=8311

For information about the College, please visit our website at http://www.albany.edu/cci.

Apply online, using Interview Exchange at http://hr.albany.edu/content/faculvac.asp

Application review will begin on February 8, 2008; position open until filled. Position

available August 2008.

The University at Albany is an EEO/AA/IRCA/ADA employer.

University of Denver
Department of Computer Science
Faculty Position

We invite applications for a tenure-track faculty position at the Assistant Professor level to begin Fall 2008. Exceptional candidates at other ranks will be considered as well. The minimum requirements are a PhD in CS or a related area by the time the appointment begins and demonstrated ability in research and teaching. The department is particularly interested in a candidate who can teach and direct research in the following areas: entertainment computing; interactive simulations and games; trustworthy computing (networks, security, privacy, fault tolerance); and systems and software engineering. The successful candidate is expected to participate fully in the department through an active research program, excellent teaching, and dedicated service.

The Computer Science Department is part of the School of Engineering and Computer Science (SECS) at the University of Denver. SECS promotes research and teaching collaborations among different disciplines. Faculty in Computer Science have unique opportunities for cross-disciplinary collaboration. For further information, visit the SECS website at

Our current faculty's research interests include algorithms, computer security, database systems, distributed systems and algorithms, graphics, networking and games, performance modeling, programming languages, and software engineering. We offer bachelor's, master's and doctoral degrees.

The University of Denver is a medium-size (11,000 students) private university. Class sizes are small, the teaching load is moderate and the salary is competitive. The university is located in an attractive residential area 5 miles from downtown Denver. Denver, with its metro area population of 2.3 million, is consistently ranked as one of the country's top five most pleasant places to live. Many of the country's best ski areas, mountain bike trails, and the 14,000 foot peaks of the Colorado Rockies are only one or two hours away.

The University of Denver is committed to enhancing the diversity of its faculty and staff and encourages applicants particularly from women, minorities and the disabled.

Application screening will begin immediately and continue until the position is filled. Applicants should submit a curriculum vitae, a statement of teaching and research interests and have at least 3 reference letters sent to www.dujobs.org.

The University of Denver is an AA/EOE. Applicants should apply online at and provide: (1) position applying for; (2) curriculum vitae; (3) three references with contact information; (4) statement of research vision; and (5) statement of teaching interests.

University of Iowa
Computer Science Department
Faculty Position
Fall 2008

The Computer Science Department seeks applications for one tenure-track assistant professor position commencing August 2008. Applications from all areas of computer science and informatics are invited. We also welcome applicants doing research at the frontiers of computing in connection with other disciplines. The Department offers BA, BS, and PhD degrees in Computer Science, and in Fall 2007 added BA and BS degrees in Informatics (see http://www.cs.uiowa.edu/Informatics). Candidates must hold a PhD in computer science, informatics, or a closely related discipline. Applications received by January 15, 2008, are assured of full consideration. Applications should contain a CV, research, and teaching statements. Please have three letters of recommendation sent directly to us (pdf email preferred).

Apply:

Via the Web at
http://www.cs.uiowa.edu/hiring/

Or by email to cs_hiring@cs.uiowa.edu

Or by U.S. mail to:
Faculty Search Committee
Computer Science Department
University of Iowa
14 MacLean Hall
Iowa City, IA 52242-1419

The University of Iowa is an affirmative action/equal opportunity employer. The Department and the College of Liberal Arts and Sciences are strongly committed to diversity and maintain ties to programs on campus that provide a supportive environment for women and minorities, such as the Women in Science and Engineering program. The strategic plans of the University, College, and Department reflect this commitment to diversity.

University of the District of Columbia
School of Engineering and Applied Sciences

The University of the District of Columbia is a comprehensive urban land-grant institution and is classified as a Historically Black College and University. The School of Engineering and Applied Sciences invites nominations and applications for the position of Chair, Department of Computer Science and Information Technology. Candidates must have an earned doctorate in Computer Science or closely related field and a strong record of teaching, research, and scholarly activities commensurate with appointment at the rank of associate professor or professor. Demonstrated knowledge and experience with ABET accreditation and with the Computing Accreditation Commission of ABET in particular is required. Candidates should have a strong commitment to undergraduate and graduate teaching. The successful candidate must have exceptional interpersonal communication and management skills necessary to promote programs and to sustain strong student enrollment. Experience with budget development and control is required. In addition to the BS programs in Computer Science and Information Technology, the School offers ABET-accredited BS degree programs in Civil, Electrical, and Mechanical Engineering, as well as programs in Aerospace Technology and Architecture. Candidates should send a letter attesting to their qualifications for the position, a current curriculum vitae, and names and contacts for at least three professional references to Ms. Mavis I. Johnson, Staff Assistant, Office of the Dean, School of Engineering and Applied Sciences at E-mail mijohnson@udc.edu. The position will remain open until filled. The University of the District of Columbia is an equal opportunity employer.

Widener University
Computer Science Department

Widener University seeks candidates for a tenure-track position as Assistant Professor in the Computer Science Department beginning September 2008. Demonstrated excellence in teaching is required. A Ph.D. in Computer Science is preferred. Candidates with any area of specialization will be considered, although teaching experience in operating systems is preferred. Candidates should send a letter of application, a curriculum vitae, and three letters of recommendation sent to: Dr. Suk-Chung Yoon, Chair, Dept. of Computer Science, Widener University, One University Place, Chester, PA 19013. Questions may be directed via e-mail to: syoon@mail.widener.edu Applications will be considered as soon as they are complete and the position remains open until filled. Widener University encourages women and minorities to apply.

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

March 12-15

HRI'08: International Conference on Human Robot Interaction Amsterdam, Netherlands, Sponsored: SIGCHI, SIGART, Contact: Kerstin Dautenhahn, Email: k.dautenhahn@herts.ac.uk

March 12-15

The 39th ACM Technical Symposium on Computer Science Education Portland, OR, Sponsored: SIGCSE, Contact: John P Dougherty, Phone: 610-896-4993, Email: jd@cs.haverford.edu

March 13-14

International Workshop on Software and Compilers for Embedded Systems Munich, Germany, Contact: Heiko Falk, Email: heiko.falk@udo.edu

March 13-17

Third International Conference on Body Area Networks Tempe, AZ, Contact: Sethuraman Panchanathan, Phone: 480-965-3699, Email: panch@asu.edu

March 16-20

The 2008 ACM Symposium on Applied Computing Fortaleza, Ceara Brazil, Contact: Roger L. Wainwright, Phone: 918-631-3143, Email: rogerw@utulsa.edu

March 17-20

Fourth International Conference on Testbeds and Research Infrastructures for the Development of Networks & Communities and Workshops Innsbruck, Austria, Contact: Miguel Ponce de Leon, Phone: 353 51 302953, Email: miguelpdl@tssg.org

March 26-28

Eye Tracking Research and Applications Savannah, GA, Sponsored: SIGGRAPH, SIGCHI, Contact: Kari-Jouko Rajha, Phone: 358-3-35516952, Email: kkr@cs.uta.fi

March 28-29

ACM Southeast Regional Conference Auburn, AL, Contact: James H. Cross II, Phone:334-844-6315, Email: cross@eng.auburn.edu

March 31- April 2

WISEC'08: First ACM Conference on Wireless Network Security Alexandria, VA, Sponsored: SIGSAC, Contact: Virgil Gligor, Phone: 301-405-3642, Email: gligor@umd.edu

March 31- April 4

7th Annual Aspect-Oriented Software Development Conference Brussels, Belgium, Contact: Theo D'Hondt, Email: tidhondt@vub.ac.be

April 1-4

Eurosys 2008 Conference Glasgow Scotland UK, Sponsored: SIGOPS, Contact: Joseph S Sventek , Phone: 44 141 330 8078, Email: joe@dcs.gla.ac.uk

April 4-5

Consortium for Computing Sciences in Colleges (CCSC) Midsouth Russellville, AZ, Contact: James R Aman, Phone: 773-298-3454, Email: aman@sxu.edu

April 4-8

SIGUCCS '08 Management Symposium Tucson, AZ, Contact: Stephanie Smith, Email: smith_s@hq.acm.org

April 5-10

CHI Conference on Human Factors in Computing Systems Florence, Italy, Contact: Mary Czerwinski, Phone: 425-703-4882, Email: marycz@microsoft.com

April 5-6

International Workshop on System Level Interconnect Prediction Newcastle, UK, Contact: Ion I Mandoiu, Phone: 404-429-4689, Email: ion@engr.uconn.edu

April 9-13

International Conference on Virtual Reality Laval, France, Contact: Jean-Francois Fontaine, Email: jffontaine@laval-virtual.org

April 13-16

International Symposium on Physical Design Portland, OR, Contact: David Pan, Phone: 512-471-1436, Email: dpan@ece.utexas.edu

PAUL WATSON

Calendar of Events

April 13-16
SPRING SIMULATION MULTICONFERENCE Ottawa, ON, Contact: Hassan Rajaei, Phone: 419-372-2002, Email: rajaei@cs.bgsu.edu

April 14-15
EUROGRAPHICS 2008 SYMPOSIUM ON PARALLEL GRAPHICS AND VISUALIZATION Crete, Greece, Contact: Daniel Weiskopf, Phone: 49-711-7816-368, Email: weiskopf@vis.uni-stuttgart.de

April 14-16
FLOPS08: 9TH INTERNATIONAL SYMPOSIUM ON FUNCTIONAL AND LOGIC PROGRAMMING Ise, Japan, Contact: Manuel V Hermenegildo, Phone: 34 91 336 7435, Email: herme@fi.upm.es

April 18-19
CONSORTIUM FOR COMPUTING SCIENCES IN COLLEGES (CCSC) SOUTH CENTRAL Corpus Christi, TX, Contact: James R Aman, Phone: 773-298-3454, Email aman@sxu.edu

April 21-25
WWW08: THE 17TH INTERNATIONAL WORLD WIDE WEB CONFERENCE Beijing, China, Contact: Yih-Farn Robin Chen, Phone: 973-360-8653, Email: chen@research.att.com

May 4-6
GREAT LAKES SYMPOSIUM ON VLSI 2008 Orlando, FL, Sponsored: SIGDA, Contact: Vijay Narayanan, Email: vijay@cse.psu.edu

May 5-7
CF '08: COMPUTING FRONTIERS CONFERENCE Ischia, Italy, Contact: Alex Ramirez, Email: alex.ramirez@bsc.es

May 5-8
FMX08: 13TH INTERNATIONAL CONFERENCE ON ANIMATION, EFFECTS, REALTIME AND CONTENT Stuttgart, Germany, Contact: Thomas Haegele, Phone: 490-714-1969-800, Email: Thomas.haegele@filmakademie.de

May 10-18
INTERNATIONAL CONFERENCE ON SOFTWARE ENGINEERING Leipzig, Germany, Contact: Wilhelm Schaifer, Email: wilhlem@upb.de

May 27-29
THE INTERNATIONAL CONFERENCE ON ADVANCED VISUAL INTERFACES Naples, Italy, Contact: Stefano Ledialdi, Phone: 39-6-88-41962, Email: levialdi@di.uniroma1.it

June 9-12
INTERNATIONAL CONFERENCE ON MANAGEMENT OF DATA Vancouver, Canada, Sponsored: SIGMOD, Contact: Laks V.S. Lakshmanan, Phone:604-822-3153, Email: laks@cs.ubc.ca

June 11-13
IDC08: 7TH INTERNATIONAL CONFERENCE ON INTERACTIVE DESIGN AND CHILDREN Chicago, IL, Contact: Justine Cassell, Phone: 847-491-3534, Email: justine@media.mit.edu

June 15-20
JCDL '08: JOINT CONFERENCE ON DIGITAL LIBRARIES Pittsburgh, PA, Contact: Ronald Larsen, Phone: 412-624-5139, Email: rlarsen@pitt.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

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 21-25
THE 35TH ANNUAL INTERNATIONAL SYMPOSIUM ON COMPUTER ARCHITECTURE Beijing, China, 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

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

July 20-23
INTERNATIONAL SYMPOSIUM ON SYMBOLIC AND ALGEBRAIC COMPUTATION Linz/Hagenberg, Australia, Contact: Juan R. Sendra, Phone: 341-885-4902, Email: rafael.sendra@uah.es

September 1-3
8TH INTERNATIONAL CONFERENCE ON INTELLIGENT VIRTUAL AGENTS Tokyo, Japan, Contact: Helmut Prendinger Email: helmut@nii.ac.jp

September 2-5
10TH INTERNATIONAL CONFERENCE ON HUMAN COMPUTER INTERACTION WITH MOBILE DEVICES AND SERVICES, Contact: Henri Hofte, Phone: 31-575-516319, Email: henri.terhoft@telin.nl

September 16-19
ECCE08: EUROPEAN CONFERENCE ON COGNITIVE ERGONOMICS Madeira, Portugal, Contact: Joaquim A. Jorge, Phone: 351-21-3100363, Email: jaj@inesc.pt

September 20-23
THE 10TH INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING Seoul, South Korea, Contact: Joseph McCarthy, Phone: 650-804-6987, Email: joe@interrelativity.com

September 22-23
MULTIMEDIA AND SECURITY WORKSHOP Oxford, United Kingdom, Sponsored: SIGMM, Contact: Andrew David Ker, Phone: +44 1865 276602, Email: adk@comblab.ox.ac.uk

September 28- October 2
ACM/IEEE 11TH INTERNATIONAL CONFERENCE ON MODEL DRIVEN ENGINEERING LANGUAGES AND SYSTEMS (FORMERLY UML) Toulouse, France, Sponsored: SIGSOFT, Contact: Jean-Michel Bruel, Phone: +33 686 002 902, Email: bruel@univ-pau.fr

October 9-10
ACM-IEEE INTERNATIONAL SYMPOSIUM ON EMPIRICAL SOFTWARE ENGINEERING AND MEASUREMENT Kaiserslautern, Germany, Sponsored: SIGSOFT, Contact: Dieter Rombach, Phone: +49-631-205-2895, Email: rombach@informatik.uni-kl.de

November 14-15
COMPUTER HUMAN INTERACTION FOR THE MANAGEMENT OF INFORMATION TECHNOLOGY San Diego, CA, Contact: Eser Kandogan, Phone: 650-694-7974, Email: kandogan@cs.umd.edu

December 9-12
4TH CONFERENCE ON EMERGING NETWORK EXPERIMENT AND TECHNOLOGY Madrid, Spain, Sponsored: SIGCOMM, Contact: Arturo Azcorra, Phone: +34-91-6248778, Email: azcorra@it.uc3m.es

December 10-13
SIGGRAPH ASIA Singapore, Sponsored: SIGGRAPH, Contact: Dr. YT Lee, Email: mvtlee@ntu.edu.sg

World Class Journals from ACM

ACM Transactions on Autonomous and Adaptive Systems

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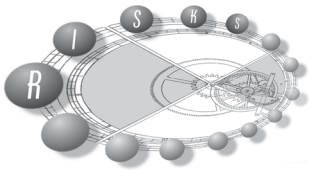

Wireless Sensor Networks and the Risks of Vigilance

When Wendell Phillips (an American abolitionist and reformer) told a Boston audience in 1852 that "Eternal vigilance is the price of liberty," he did not anticipate the advent of wireless sensor networks (WSNs). WSNs are a new technology that will help us be vigilant. Wireless networks and sensors are not new. However, deploying very large numbers of very small sensing devices (*motes*) is new.

WSNs are distributed systems programmed for specific missions, to capture and relay specific data. For example, WSNs can check a vehicle's registered identity, location, and movements. Data recorded by sensors embedded in the vehicle can be cross-correlated with data recorded by sensors embedded in sidewalks and roads. With a vast WSN of this type available to them, authorities could monitor driving conditions and instantly recognize traffic problems. Drivers could benefit from such vigilance and the rapid response that it facilitates.

The obvious downside in this example is a further erosion of our privacy. The cross-correlated data can be a bounty for law enforcement. If roads are seeded with sensors enforcing speed limits, we might expect to receive a ticket every time we exceed them. Authorities will benefit from such vigilance, too. There would be less need for patrolling highways or for pulling anyone over for speeding, because automatically generated fines could be issued to vehicle owners.

Cars and roads are merely the tip of the iceberg for WSN applications. There are already commercially available sensor systems for habitat oversight, environmental surveys, building and structural integrity testing, spotting containers and other shipping cargo, border patrol support, fire and flooding alerts, and many other vigilance situations. Industry analysts predict the market for WSNs will surpass $7 billion by 2010.

Potential uses and benefits of WSNs are difficult to gauge; so are the risks associated with their proliferation. Personal computers 30 years ago and cell phones 15 years ago can serve as templates for what we can reasonably expect. Today, motes are costly and big. Early PCs and mobile phones were heavy and expensive. Eventually sensors will be small enough to go unnoticed and inexpensive enough to be scattered almost anywhere.

Power, storage, and communication range will be challenges for WSNs, just as they are for laptop computers and mobile phones. Security is also a serious concern. Power drain in sensors spawned many clever, cost-effective workarounds, skirting security difficulties. Synchronizing sleep and wake cycles maximizes battery life, but exposes sensors to attacks that can force sensors to sleep (stop working) or stay awake (waste energy).

Sensors are more vulnerable to attack than PCs or cell phones. A standard off-the-shelf serial board can be used to change data via sensors' debugging interface. Data diddling could render a WSN unreliable. WSNs may give governments new tools to watch us, but hackers will relish new ways to spam and phish. Revenue-producing WSNs such as those monitoring traffic must be maintained, periodically tested, and upgraded. Maintaining WSNs deployed in rough terrains or hazardous conditions may not be possible. Motes may have to operate unattended, and those without power may remain unreplaced. Abandoned motes will be opportunities for new forms of data theft. Recovering dead motes to prevent staggering pollution problems will require "sensors sensing sensors"—with as yet unknown techniques.

Although power and security problems are not yet solved, it is prudent to begin examining the risks that would be posed by widespread deployment of WSNs. As with all advanced technologies, WSNs compel us to balance what's helpful (enhanced ability to observe) with what's harmful (abuse of this ability or undue expectation of its reliability). Performance of large and complex WSNs may be affected by a few malfunctioning sensors, which might be difficult to discover.

The risks of deployment must be compared with the risks of non-deployment. For some locations, the cost-benefit analysis may be simple and decisive. WSNs will appear wherever it makes economic sense to deploy them, or when political goals justify their deployment. Anti-terrorism efforts will add round-the-clock attention to our already well-documented lives. Phillips warned that if we want to be free, we had to be vigilant. He could not imagine we would risk trading freedom for vigilance; with WSNs, it can happen surreptitiously. C

Xiaoming Lu (lu@cs.ucdavis.edu) is a Ph.D. candidate at the University of California, Davis. **George Ledin, Jr.** (ledin@sonoma.edu) is a professor of computer science at Sonoma State University, CA.

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