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Ecological Computing

For the past few years, environmentalists have been watching the Internet with the wide-eyed wonder of amateur cooks at the Willams-Sonoma outlet. The possibilities are certainly enticing: government programs can go online, businesses can report their emissions electronically, and citizens can access information about local or national environmental issues on the Web.

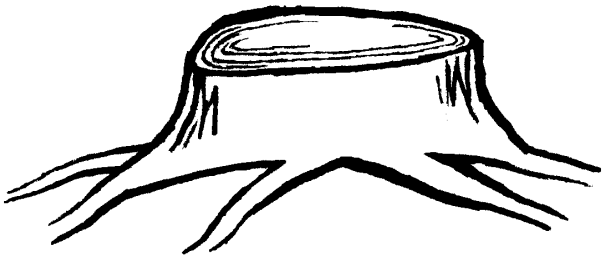
Far away though, across a large cultural and intellectual divide, the high-tech industry watches the environmental community with suspicion and apprehension. After all, these are the people who can turn a perfectly good day in Industrial America into a public relations nightmare, or worse still, permanent employment for the legal department.

The players on both sides of this divide are missing the point. Environmental activists can learn much from technologists, and technologists can learn much from environmental activists. Together they can tap a new world of technology that, unlike smoke-belching factories of the past, actually helps the environment. And that benefits everybody.

Don't count on the environmental community seeing these applications first. Real change calls for visionaries, entrepreneurs and bleeding-edge techies who understand not only the protocol stacks of the Internet world but also wireless technology, micro electrical-mechanical systems and ubiquitous computing.

If we can lay a pervasive network across the planet, we should also be able to design it to help us understand and address tomorrow's environmental challenges, ranging from monitoring global biodiversity to sensing millions of low-level sources of pollution.

"Those worried about protecting the web of life will benefit from those building the Web of the future."



Sound far-fetched? Remember that only 2 percent of the 8 billion computer processing units produced this year will end up in computers. The rest will be embedded in the world around us. As these microprocessors become increasingly interconnected – with each other, the Internet, and the physical world – they will form the technological foundation of the next environmental revolution.

With pervasive and embedded intelligence, our manufacturing systems could become self-managing and more self-regulating. We are a few years away from inexpensive radio frequency tags with enough storage to provide a unique indentity to all products in the global supply chain. Combine this capacity with micro and nano-scale sensors and you have products and parts that could keep track of themselves, help manage inventories, know when they need repair or replacement and find their way back to the right place to be remanufactured or recycled.

These systems would be capable of acting independently in response to their environment without requiring constant, and often expensive, human intervention. Industrial systems would begin to operate more like ecological ones, continually aware of their surroundings, self-organizing and perhaps even engaging in micro-auctions for balancing energy loads.

Equipped with a new generation of sensors, automobiles and trucks could monitor their own emissions and download them at a service station, to a home computer, or transmit the data in batches over cellular networks. When cars can talk to each other we can begin to create dynamic networks that can be optimized to reduce congestion, cut air pollution, speed up just-in-time deliveries, or help people find the closest available parking space in an unfamiliar city. This is about more than convenience. We waste enough energy sitting in traffic jams each year to run our entire domestic airline fleet.

But let's not stop there. The "smart" house and workplace of the future will be intelligent about its internal environment. Unlike our ancestors, most of us now spend 80 to 90 percent of our time indoors, yet we know amazingly little about our exposure to indoor air pollution and the relationships between indoor and outdoor exposures. In a smart-sensor world, that changes.

Imagine also that we begin to understand our susceptibility to diseases that are related to environmental exposures – a fair bet in five years given a sequenced human genome, advances in functional genomics and ever-cheaper genetic screening devices like gene chips. Suddenly, real-time exposure data from sensors in our pagers, cell

phones or Reeboks becomes much more valuable in preventing adverse medical outcomes.

As networked sensors become dramatically less expensive and have wireless capability built into them, we may find them in a Midwest cornfield, helping farmers optimize water and fertilizer use and minimize the use of harmful pesticides. Sensor systems could go where we cannot, monitoring environmental damage in an oil spill or forest fire, tracking ocean currents or helping biologists unravel the wonders of a rain forest canopy. We could begin to instrument whole ecosystems, using ground-based sensors networked to the next generation of satellites to understand subtle but far-reaching changes in land use and vegetation

Can any of this happen? Maybe, but only if the computer science and environmental communities begin to talk. Think about what happened when the IT and medical communities started serious collaboration more than 15 years ago. The result has been nothing short of spectacular in terms of new diagnostic and imaging capabilities. This marriage has also transformed the way we and our families educate ourselves on the latest treatments and research findings by immersing ourselves in medical Web sites when serious illness threatens.

The collective challenge we now face is how to move from our traditional focus on *personal* computing to a broader concept of *ecological* computing that utilizes the notions of complex adaptive and self-organizing systems in the designs of a new kind of information fabric.

After all, the information revolution is not just about the manipulation of information. It is about the conscious design of new systems for living and learning that can provide broad social benefits while guaranteeing privacy of individual action. It is time to put information technology in the service of our environmental goals and aspirations. We may find that the computer science community has something to learn from ecologists and biologists and, conversely, those worried about protecting the web of life will benefit from those building the Web of the future.

We may also discover that sound environmental management, our moral obligation to the planet and business opportunity can converge. Government, industry, foundations, universities, NGOs and the public need to realize that technological innovation, responsibly applied, will mean a better environment at far less cost for all of us.

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