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Denial-of-Service Attacks to UMTS

Elisa Bertino, Purdue University

This installment highlighting the work published in IEEE Computer Society journals comes from IEEE Transactions on Dependable and Secure Computing.

Cellular communication networks are among today's most critical infrastructures, making possible important applications including location-based services, emergency management, and continuous health-care monitoring. Consequently, cellular communication networks have been extensively analyzed to identify

as they identify a novel *denial of service* (DoS) attack against universal mobile telecommunication system (UMTS) infrastructures. A DoS attack is disruptive and typically prevents legitimate users and applications from accessing networks.

The new attack operates at the user level and thus doesn't require hacking a network's intra-operator facilities.

It's crucial to research and identify new threats and vulnerabilities to improve network defenses.


security threats and devise corresponding mitigation techniques. However, because achieving 100 percent security is impossible and new attacks are continuously being reported, it's crucial to research and identify new threats and vulnerabilities to improve network defenses.

In "A Denial of Service Attack to UMTS Networks Using SIM-Less Devices" (*IEEE Transactions on Dependable and Secure Computing*, vol. 11, no. 3, 2014, pp. 280–291), Alessio Merlo and his colleagues make an important breakthrough in cellular network security

It also doesn't require that mobile devices be equipped with a valid subscriber identity module (SIM), making it fairly easy to carry out. This attack specifically targets the functionality of the home location register (HLR) database, which stores information about mobile subscribers and rules for call blocking and forwarding. Because the HLR is a central component of a cellular network, its inability to respond to legitimate users' requests makes the network's communication services unavailable to these users, disrupting network coverage. The article provides

details about the attacking devices' design and an in-depth analysis showing that this new attack can reach cellular networks with an order of magnitude fewer resources than previous attacks.

What distinguishes this new attack from previous attacks is that it doesn't require using a *botnet*. A botnet is a network of mobile devices owned by legitimate users that can be coordinated by a command-and-control center to perform attacks unbeknownst to these users. The article shows that unlike botnet-based attacks, the new attack isn't impacted by user mobility, so the attack can be placed very precisely. The article doesn't propose a solution to protect against these attacks, so further research should look into identifying defenses, such as those based on anomaly detection.

This article is an important reference for researchers in academia and industry interested in securing cellular networks, as it demonstrates the importance of identifying all bottlenecks in a network infrastructure and making sure these bottlenecks can't be exploited by attackers. It's also a must-read for anyone interested in testing the robustness of HLR implementation solutions. 

ELISA BERTINO is a professor in the Computer Science Department, Cyber Center, and the Center for Education and Research in Information Assurance and Security (CERIAS) at Purdue University. Contact her at bertino@cs.purdue.edu.



Selected CS articles and columns are also available for free at <http://ComputingNow.computer.org>.

Magazine Roundup

The IEEE Computer Society's lineup of 13 digital magazines covers cutting-edge computing topics ranging from software design and computer graphics to Internet computing and security and privacy, from scientific applications and machine intelligence to cloud migration and microchip manufacturing. Here are some highlights from recent issues.

Computer

Big data is sparking fundamental changes in scientific

research methodology and how businesses develop products and provide services. The March 2015 issue of our flagship publication, *Computer*, surveys **big data management** as we as we shift toward gigabit networks, gigapixel cameras, and a data-intensive Internet of Things.

IEEE Software

Optimal **release engineering** requires a pipeline for transforming source code into an integrated, compiled, packaged, tested, and signed product ready

for release. *IEEE Software's* March/April 2015 issue focuses on the challenges release engineers face and offers some practical solutions.

IEEE Internet Computing

An exponentially expanding Internet of Things raises questions about how best to design, implement, and validate scalable **IoT software**. In the March/April 2015 issue of *IEEE Internet Computing*, writers with diverse interests tackle specific scalability problems associated with the IoT.

Computing in Science & Engineering

High-performance computing has changed drastically in recent years, with various computational accelerators now common for many scientific

calculations. Such accelerators require new programming paradigms to account for more **heterogeneous architectures**, the subject of *CiSE*'s March/April 2015 special issue.

IEEE Security & Privacy

Users often don't trust shared cloud environments for performing computation on sensitive data. To address this concern, "Computing with Data Privacy: Steps toward Realization" from the January/February 2015 issue of *IEEE S&P* presents two new methods for **general-purpose computation on encrypted data**.

IEEE Computer Graphics and Applications

Last year, *IEEE CG&A* asked editorial board and advisory council members to describe where they see their fields headed in coming years. For the January/February 2015 issue, editor in chief L. Miguel Encarnação has compiled their responses addressing **future directions for computer graphics and applications**.

IEEE Intelligent Systems

What is **big data software**? Can it be engineered? Answering such questions requires exploring the term *big data* and reaching consensus on how big data software can be created and function. In *IEEE Intelligent Systems*' January/February 2015 issue, authors from Florida Institute of Technology survey current research.

IT Professional

Change is a constant in IT security: organizations must manage patches daily, continuously monitor for vulnerabilities and attacks, and install an endless stream of new releases for application software. The January/February 2015 issue of *IT Professional* focuses on **adapting securely to change**.

IEEE Micro

The high availability and fast response time required for mobile systems put great stress on power, energy, and thermal capabilities. For *IEEE Micro*'s January/February 2015 issue, guest editor Calin Cascaval from Qualcomm brings together articles addressing the complexity of this **new mobile computing paradigm**.

IEEE MultiMedia

With widespread access to highly interactive multimedia devices, users are increasingly connected to interfaces involving sound. This **sonic interactivity** opens multiple new possibilities for digital display and retrieval, as *IEEE MultiMedia*'s January–March 2015 special issue explores.

IEEE Annals of the History of Computing

Accounts of the **slide rule's introduction and early use** appear in many 18th- and early 19th-century American sources. In the January–March 2015 issue of *IEEE Annals*, Peggy Aldrich Kidwell from the

Smithsonian Institution examines initial confidence in the instrument's practical potential and also its relatively slow popular diffusion.

IEEE Cloud Computing

Smart evacuation systems must extract meaningful information from multiple sources in real time, while avoiding unnecessary data transmission or storage. The November 2014 issue of *IEEE Cloud Computing* looks at **cloud-based smart evacuation systems**, with a particular focus on emergency management.

IEEE Pervasive Computing

Bridging the analog and digital worlds, **physiological computing** poses data acquisition challenges—for example, the need for higher signal-to-noise ratios and greater sampling rate accuracy. "Biosignals for Everyone," from the October–December 2014 issue of *IEEE Pervasive*, presents a platform designed for physiological data acquisition.

Computing Now

The Computing Now website (<http://computingnow.computer.org>) features up-to-the-minute computing news and blogs, along with articles ranging from peer-reviewed research to opinions by industry leaders. 📱



Selected CS articles and columns are also available for free at <http://ComputingNow.computer.org>.

3D Technologies: A Kind of Magic

A clever new-style magician has recently popped onto the scene: Simon Pierro, the iPad Magician. His tricks include producing a real pencil by apparently pulling the image of one from a tablet screen, and taking a selfie with several audience members that he makes “jump” into a real picture frame as a physical color photo anyone can hold. You might call him a “digital prestidigitator,” transforming 2D pixel images into 3D realities through a process of “magic.”

But his magic has its real-life counterparts in the various 3D technologies now entering mainstream consciousness. 3D imagery, rooted in the development of stereoscopic photography almost two centuries ago, has found its way into multiplexes from Pocatello to the Punjab. Holography—a technology that won physicist Dennis Gabor a Nobel prize in 1971—is now used in applications ranging from medical imaging to ID security to high-density data storage. And even Walmart is selling 3D printers for home use.

This month's *ComputingEdge* starts off with a group of articles from recent CS publications describing various 3D applications. First, *Computing Now's* editorial content manager Margo McCall, three contributors writing for *Computer's* December Making in the 21st Century issue, and

an installment of *IEEE Internet Computing's* Peering column survey multiple uses for 3D printing, from the practical to the whimsical.

Next come two considerations of 3D-prototyping applications in business and industry: one from *IT Pro*, which looks at Taiwan's developing tool industry, and one from *Computing in Science & Engineering*, which presents a case study from Goodyear.

Finally, two articles take a more “humanistic” approach: an Education column from *IEEE Computer Graphics and Applications* shows ways to use 3D-design environments like Minecraft to teach students modeling and programming concepts, and an Artful Media column from *IEEE MultiMedia* suggests concrete applications to enrich museum-goers' experience of cultural objects.

Beyond the sphere of 3D, you'll find other articles of timely interest: an examination of machine-to-machine communication from *IEEE Software*; an appreciation from *IT Pro* of computing pioneer Alan Turing, who's just reached wide recognition through an Oscar-winning film; and a piece from *IEEE Security & Privacy* on Wi-Fi sniffing.

Not all magic, maybe, but pretty amazing nonetheless. 🍷

3D Printing Ready for Prime Time

Margo McCall

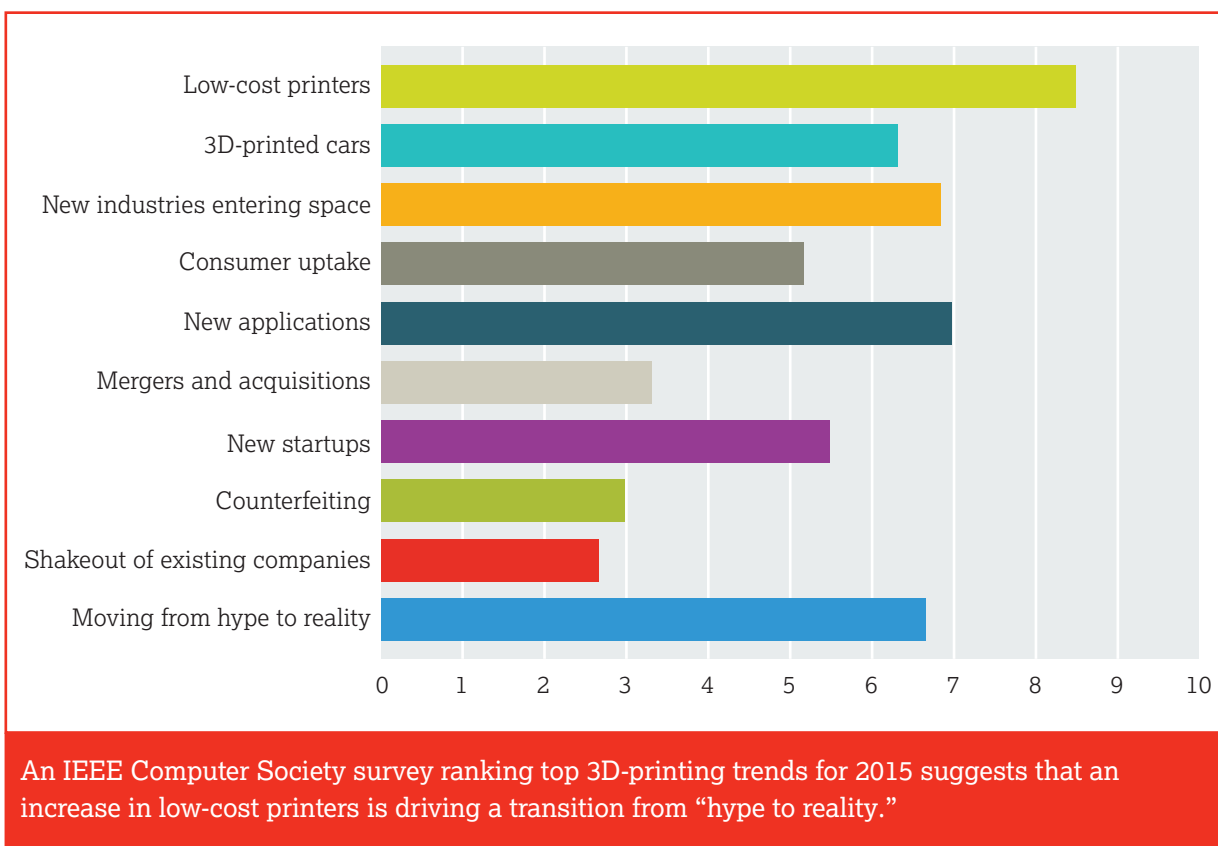
When 3D printing is helping save lives on *Grey's Anatomy*, you know the technology has hit the mainstream.

For a recent episode of ABC's long-running hospital drama, the producers asked industry leader 3D Systems' Medical Modeling division (www.medicalmodeling.com) to design and 3D-print an anatomically exact model showing a tumor afflicting a patient's heart and liver, based just on an image a staffer sketched on a napkin. And the 3D Systems team—accustomed to working with real-world hospitals—produced a perfect specimen to order in only four days.

From Plastic Forks to Human Veins

The technology has come a long way since *Grey's* Sloan Memorial debuted its 3D printer during the 2013 season, and the first thing it produced was a plastic fork. But as Dr. Meredith Grey proclaimed then, "Forks today, tomorrow portal veins for actual people."

Although medical applications for 3D printing—from pre-surgical visualization and treatment planning to prosthetics and replacement body parts—may command the spotlight, medicine is not the only field where 3D printing is making a difference.



An Auto Industry Revolution

Later this year, Local Motors is scheduled to begin producing the first 3D-printed car. The Strati, which recently premiered at the North American International Auto Show (NAIAS) in Detroit, is manufactured from carbon-fiber-reinforced plastic, and can be printed in about 44 hours.

Local Motors plans to produce the cars in 100 microfactories around the world, touting them as a replacement for traditional auto plants that require greater time and consume considerable energy. The US Department of Energy’s Oak Ridge National Laboratory and the materials company Sabic are assisting in the endeavor.

The automotive industry was an early 3D-printing adopter, and has been using the technology for low-volume prototyping of everything from individual auto parts to complete engines and concept cars. Analysts with the research firm SmarTech believe the industry is at an inflection point,

driven by record volumes for 3D-printed prototype parts and leading manufacturers’ use of functional parts in test vehicles and engines.

According to SmarTech, the trend “represents a shift in 3D-printing adoption towards higher value applications and is an early step towards acceptance of 3D-printed end-use parts in automobiles.”

The auto industry is expected to be a big purchaser of 3D-printing materials and software in years to come. By 2019, SmarTech analysts forecast it will account for more than \$1 billion in goods and services.

How Far We’ve Come

While 3D printing has been around since the late 1980s, until recently the high cost of printers made its use prohibitively expensive for all but a few design and prototyping opportunities. But with 3D-printer costs now dropping, uptake is forecast to take off. Market research firm Gartner expects

3D-printer sales to more than double this year to 217,350, from 108,151 in 2014, and reach 2.3 million worldwide by 2018.

Lower printer costs, higher quality, and a wider range of available materials are driving growth in the enterprise market. And in the consumer market, the race is on among a surge of startups competing to produce consumer 3D printers that sell for under \$500.

“Democratic” Manufacturing

For both consumers and the enterprise, 3D printing is expected to lead to “democratization” in manufacturing. The technology has the potential to inspire new market entrants, improve traditional design and prototyping, and create new products and markets.

Canalys senior analyst Tim Shepherd notes that faster print times and the ability to print objects in greater combinations of materials, colors, and finishes are also contributing factors to this predicted growth. Canalys sees 3D printing having

a dramatic impact over the next five years across numerous sectors: engineering and architecture, aerospace and defense, and, of course, medicine.

Print-to-order services that produce items customized to individual specifications are another expected growth area, offering convenience and significant manufacturing efficiencies, according to Canalys. Items can be printed locally, rather than sent off to distant—often offshore—manufacturing facilities, helping homegrown economies.

Looking to the Future

With a forward look at these groundbreaking trends, IEEE Computer Society’s March 2015 Rock Stars of 3D Printing event in San Jose brings together speakers from Autodesk, GE Global Research, HP, Intel, the National Institutes of Health, and others to talk about how the 3D-printing revolution will change the way we produce everything from automobiles to prosthetics to food, make it possible to create things barely imagined (such as replicating human organs), dramatically reduce costs and waste, place “manufacturing” within every individual’s reach, and increase innovation exponentially.

And, given the pace of change, who knows what the next 10 years will hold?

If *Grey’s Anatomy* is any indication, though, 3D printing today is definitely ready for prime time. 🍷

Margo McCall is editorial content manager for the Computer Society’s Computing Now destination site (<http://computingnow.computer.org>). Have an idea for an article or wish to contribute? Contact Margo at mmccall@computer.org.



Selected CS articles and columns are also available for free at <http://ComputingNow.computer.org>.

The following three articles originally appeared in a special issue of *Computer* magazine (vol. 47, no. 12) exploring the Maker Movement and its potential impact on engineering and technology, guest-edited by Intel's resident futurist Brian David Johnson. He writes that these authors "see the world in a unique way and ... challenge the very nature of design: what's made, how it's made, how projects are chosen to begin with."

Contact Johnson at brian.david.johnson@intel.com.

Experiments in 3D-Printed Design and Distribution

Carla Diana

Every few days, I wake up and check my online accounts to find that another of the toy sheep I designed has been created somewhere in the world. It may be in a library in Iowa or a garage in France or a classroom in Russia. Often the sheep just exists on its own, appearing as a photograph in my email or on an Instagram post. Sometimes it sits alongside a 6-inch-tall toy version of me, or a model of a character I call LEO, the walking, talking, 3D-printing robot—all objects I designed and prototyped in my studio and then distributed as files online.

Only a few years ago, this phenomenon would have been unthinkable. As a professional designer, I'm well-schooled in the ways of product manufacture and distribution. I've always known that, to appear anywhere but inside my studio, most designed items had to be mass-produced. For a design of mine to make it into people's hands, a mold had to be made, hundreds of thousands—if not millions—of parts had to be produced in bulk and assembled at a factory, and the finished items had to be packaged and stored in a warehouse. Then, they would make their way in trucks onto store shelves, where an end user could purchase one and take it home.

What makes my most recent collection of product designs so different is that none have gone through the typical manufacture and distribution process. I created them to be made on a 3D printer; their files are available online either through a popular 3D file-sharing platform like Thingiverse (www.thingiverse.com) or via a service that can 3D-print files and ship them to customers.

I didn't have to wait months for factory-tooling methods and logistics or depend

on a client investing tens of thousands dollars, gambling on the success of my design. Instead, I created the parts for my toy sheep in my two-person studio and generated a virtual file to upload to a server; within as little as a day, my product was a real, physical object living in homes, schools, and offices around the world. The sheep files have been downloaded from Thingiverse over 2,500 times.

Is this process a new business model for designer entrepreneurs? Quite possibly, though it's still hard to tell. My first foray into the newly emergent 3D-printing economy was largely an experiment. I created a book to share my own excitement about 3D-printing technology and to illustrate several possible scenarios for printed-object design and distribution in the future. A book about 3D printing didn't seem complete without photos of actual 3D-printed objects, so I designed things like jewelry, planters, toy musical instruments, and chess pieces to fit with the characters and storylines I'd created.

While I was at it, I decided to make all the objects available to readers as free downloads. This way, they could hold what they were reading about in their hands, or reflect on the story later when they saw the objects on a desk or shelf. In writing the book, I considered the 3D data as much

Carla Diana is a product designer, author, and educator whose focus on future visions for new technologies has led her to design products ranging from robots to connected home appliances. She is a fellow with the firm Smart Design (<http://smartdesignworldwide.com>) and a lecturer in the University of Pennsylvania's Integrated Product Design Program. Her book LEO the Maker Prince (www.leothemakerprince.com) is the world's first children's book on 3D printing.



Carla designed and prototyped a 3D modern sculptural toy sheep (above left), then distributed files for it online; the original has been re-created by people all over the world. LEO (below left) is a walking, talking, 3D-printing robot from Carla's book *LEO the Maker Prince*. Carla also created a model of herself for her book (above right); it often accompanies her sheep in the photos people post. Other objects she created include toys and jewelry.

a part of the content creation as the text and illustrations. Although I'm not selling the objects per se, I profit from them as part of the book's larger context. Readers who don't have access to a 3D printer can acquire the characters and products featured in the story from a 3D-printing service such as Shapeways (www.shapeways.com), which uses my files to make the objects on demand and then ships them directly to customers without my ever having to touch inventory or handle fulfillment details.

What's even more exciting is that people can customize or modify what's printed, creating different colors or even shapes. When I first unleashed Carla and LEO's sheep on the world, it had a white body and black legs. I guessed that a black sheep would appear somewhere, and, sure enough, a devious-looking reverse-color version of my original design, created by a user in South Africa, showed up on Thingiverse within weeks.

Although I offered these files for free, my larger interest was experimenting to explore the world of globally distributed 3D files. Would people download the files? Would my designs work, from a mechanical standpoint? What would quality be like when I have no control over the type of printer and filament material used?

I'm still discovering answers to these questions. But for the most part, the answer to my main question—"Is it possible for a designer to develop physical products that can

be multiplied and distributed digitally?"—is a resounding "Yes!" Naturally, though, making something like this work as a business requires that people pay for downloads, which means adopting an entirely new mindset from what we're used to. How much people are willing to spend and how makers can accurately determine value are questions still open for debate. But MakerBot (www.makerbot.com), the popular 3D-printer manufacturer, and 3DFileMarket.com are already selling files for download; in particular, MakerBot launched a new store last month that allows visitors to download files of toys and toy accessories. And since printers can be connected directly to the Internet, customers can even purchase a file online and have it immediately sent to their printer for fabrication.

Generally speaking, we're still pioneering 3D-printing file distribution, a situation many legal experts compare with the early days of MP3 sales. Because it's easy to copy

and share files online, many sources for illegally downloading file copies will inevitably crop up. Another problem is that as 3D scanners become increasingly sophisticated, there'll be nothing to stop people from copying an object image, say a lampshade or small sculpture, and then producing a physical replica on a home 3D printer or through a 3D-printing service. But, then, why should there be?

As a designer whose livelihood depends on the value of intellectual property, I'm naturally concerned about the potential that digital replication holds for diluting that value. But I also see in digital replication even more enormous potential for empowering designers and entrepreneurs to start new businesses that would never have been possible before.

We still have a long way to go before a 3D-printed economy becomes reality. Now, objects produced through online services lack customized branding, and quality control is out of a designer's hands. Material selection is relatively limited, and parts are still more costly than if they were mass-produced. Moreover, if a product I've created is sold as a file for download and home 3D printing, I'll have absolutely no control over the material or even the printer a purchaser uses.

Nevertheless, the momentum is under way, and I can't wait to try out another experiment and see how a new

set of designs travels from my computer and out into the world.

Builtbot

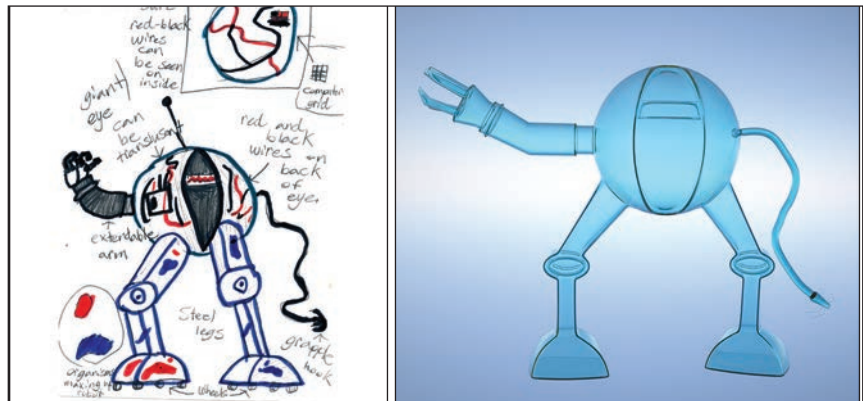
Nicholas Nakadate

Kids love robots. Kids also have great imagination and creativity. Combining the two is a goal of Builtbot (<http://builtbot.com>), which I conceived as a high-tech fundraiser for Chief Joseph/Ockley Green, a Portland public K-8 school that my 5-year-old son, Jackson, will attend.

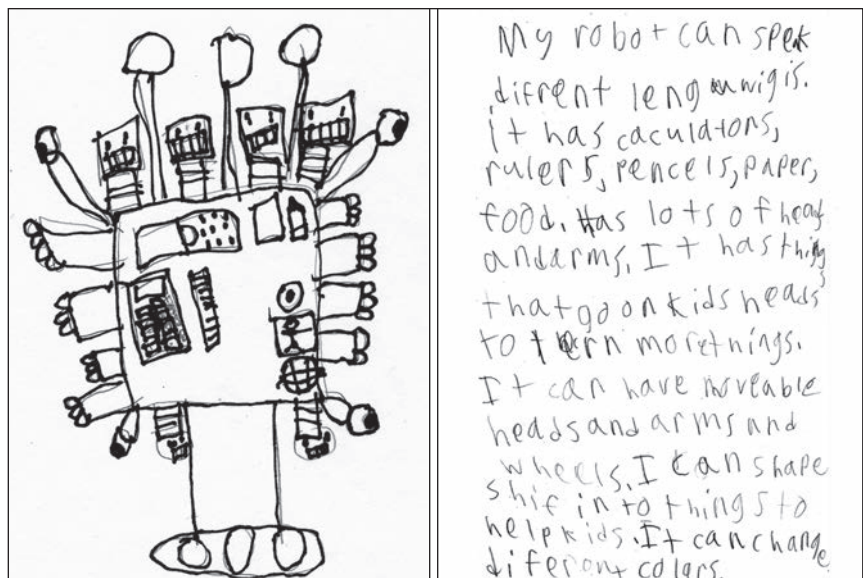
Builtbot bridges art and science with drawing and 3D printing. The Builtbot program has had a trial run supervised by art teacher Beth Bundy and science teacher Kristin Moon. Students in Ms. Bundy's three fifth-grade classes designed robots, but not just any robots. They first had to describe how the robot they drew would help them or someone else in their lives.

Once the robot designs were complete, we selected several to 3D model and print using the MakerBot Replicator desktop printer in Ms. Moon's classroom. Additional 3D printing took place at ADX (www.adxportland.com), a local workshop. The process showed students the challenges involved in 3D printing but, more importantly, helped to demystify how robots are made by personalizing the various steps. Participating in the project helped me begin to answer the question, "Where will all the robots in our future come from?"

Currently, Ms. Bundy, Ms. Moon, and school principal Molly Chun are working with Builtbot and ADX on a proposal for a pilot STEM program at Chief Joseph/Ockley Green that aims to span all grades and challenge students in designing and



Students at Chief Joseph/Ockley Green public school in Portland described and designed robots that were 3D printed.



Kids imagine and draw, shape, or model robots based on their idea of how the robot will help them or perform a task.

Nicholas Nakadate is a visual effects artist for feature film and commercials, now working on a variety of interactive, animated, and VFX projects in Portland, Oregon. Nick's son, Jackson, is an energetic advocate for bringing drawings and digital art to life through 3D printing. Contact Nick at nick@builtbot.com.

making. Potential media for the program includes clay, Legos, the Arduino platform, and more.

After seeing the test 3D print of the beetle-building robot he'd designed, Jackson was happy. "It takes a long, long time to make a real robot," he said, "but

drawing them is fun. I want to make more!"

Get involved at Builtbot, and help make Chief Joseph/Ockley Green students' futures—and yours.



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Braigo: Building for Social Good

Shubham Banerjee

I've loved Legos since I was 2 years old. And last December in my family's mail I noticed a letter that said, "Help blind people with donations." This is how the two things came together.

I didn't know anything about braille, so I asked my parents how blind people read. And they told me, "Google it!" After some research, I discovered that the assistive technologies currently available are either too expensive or difficult to obtain for many people without government or nonprofit sponsorships.

According to the World Health Organization, there are an estimated 285 million visually impaired people worldwide, and 90 percent of them live in developing countries. At this moment, the cost of a basic braille printer is more than \$2,000. Thus, many millions of people across the world have limited access to this technology. If we could reduce the cost by 75 percent, to below \$500, it would be more widely available.

To make it possible for the masses to easily assemble a braille printer, basic do-it-yourself ability is key. The kit should be readily available in stores or procurable online from reputable websites to make the adoption process easy. Most printers operate in X-Y-Z coordinates—X, to move the print head; Y, to push the paper; and Z, to print or not to print. The printer also has to be compact and self-explanatory.

After studying the braille language, I understood that visually impaired individuals use their fingers to feel bumps on paper and other surfaces that are combinations of six dots. I decided that if we could make a printer that prints by making holes in paper as a mirror image of the letters, then by flipping the page, we should be able to translate letters into braille.

For my experiments, I used a common Lego Mindstorms EV3 robotics kit to build a DIY braille printer I imagined and programmed the device to print in braille. I worked with the constraint that all the parts for the printer should come from one kit, with maybe some low-cost readily available add-ons.

Using rapid prototyping concepts, I built models that I then programmed to see if I was able to get the results I wanted. I had to build and break up seven different models before I settled on a final one that was able to print six dots in the desired sequence according to the braille standards. After this, I programmed the letters A to Z. I used normal calculator paper to provide the proof of concept. I called my printer Braigo.

I've validated version 1.0 of Braigo

along with some potential small software updates at the Santa Clara Valley Blind Center based in San Jose, and also working with Hoby Wedler—he's a blind doctoral student in computational chemistry at UC Davis. I'd say that the first prototype of the proof of concept has been successful. I achieved an 82 percent reduction in cost and have been overwhelmed by encouraging feedback from both sighted and

blind people. By offering the building instructions and software as open source, I'll provide a low-cost printer alternative for the visually impaired community.

My dad was my guide whenever I got stuck even though he doesn't know much about Lego robotics. Sometimes his suggestions worked, sometimes not. He used to sit down with me evenings at the kitchen table, while he continued his conference calls and other business as I was building my models. For couple of weeks, I put in very long days. I'd start working on Braigo after I finished my homework, and some nights I was awake until 2 a.m. But it was all worth it.

I'm now working on Braigo 2.0, which I plan to market as a consumer product. Currently, my vision is for a braille embosser that retails for less than \$200. If I could achieve that, it would be amazing.

You can read about my project and awards at www.wikipedia.org/wiki/braigo and at www.facebook.com/BraigoPrinter, where I regularly update the project's status.



Shubham holds a model of Braigo, a portable braille printer he constructed using a Lego Mindstorms EV3 robotics kit. Below is a close-up of his model.

Shubham Banerjee is a middle school student, inventor of Braigo, and founder of Braigo Labs (www.braigolabs.com), which focuses on creating innovative technologies for social good. Contact him at sbanerjee2001@gmail.com.



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The Age of DIY

Charles Petrie • University of St. Gallen



Recently, a friend asked me to write about Bitcoin. This has always been an interesting topic. I wrote about electronic cash in 1997,¹ when the November/December issue of this magazine ran a theme on the topic. My advice then, as now, was “Hold on to your wallet.”

After looking into Bitcoin, I realized I couldn’t add much to what you can get on this interesting topic yourself, starting with an excellent Wikipedia article (<http://en.wikipedia.org/wiki/Bitcoin>). Bitcoin isn’t a Ponzi scheme. Mining bitcoins might seem a bit like a Ponzi scheme because early and informed adaptors have an advantage, but no promise of large returns is made for late adaptors.² The system is designed to even out. Someone has been indicted for a Bitcoin-based Ponzi scheme, but the case could have been based on any currency (www.sec.gov/News/PressRelease/Detail/PressRelease/1370539730583). And Bitcoin is just a currency (http://blogs.wsj.com/moneybeat/2013/08/07/bitcoin-money-says-judge/?mod=trending_now_5). It’s no more an artificial fiat currency than is the dollar. In fact, it’s better in this respect.

The basic value of bitcoins is based on the cost of computing power to mint them, and the shared protocol for doing so ensures that — unlike the dollar — only so many will ever be minted or mined. Bitcoins’ current dollar value fluctuates wildly now, but that’s just currency speculation consistent with a relatively small number of bitcoins in circulation and use. If I could afford to speculate, I’d be mining them now. But there is a substantial cost to buying the equipment and running it continuously to have a chance of earning some bitcoin. So on one hand, you’re speculating with this investment in equipment, and on the other, this is the intrinsic value of the currency. Bitcoins are almost as anonymous as cash and almost as

easy to transfer digitally as any other currency. They are somewhat more subject to hacking, and you can’t insure them. Lose your hard drive, lose your stash. I don’t see a big problem with bitcoins, and the fact that some governments don’t like them is in their favor. But you can figure all this out for yourself with a little reading. (If you come to different conclusions, please write a letter to the editor.)

What did catch my attention is that Bitcoin is do-it-yourself (DIY) money enabled by novel uses of the Internet — that is, you can now use the Internet to turn data into money. There are other uses.

From Data to Tools

We all know that you can find any information you need on the Web. You want to learn how to tie a bowtie, wire your house, or improve your makeup skills? It’s all there. You don’t have to ask anyone anymore. But what’s happening is more than just being able to access tutorial YouTube videos. It’s even more revolutionary than massive open online courses (www.mooc-list.com), which are another kind of DIY. We’ve gone beyond information.

First, tools are available for building things on the Internet that you couldn’t do yourself previously. Once, you could create your own websites with WordPress and other software. Now, you can do Web *design* as well (<http://readwrite.com/2013/07/31/pagelines-design-management-system-website-design-review#awesm=~odl26VyyY2YeA0>). You don’t have to simply take the templates that website creation tools give you.

Then there are sites with kits that let you build actual things at home. Consider *Make* magazine and the Maker Faire (<http://makezine.com>). Consider inexpensive, home-built airplanes from open source designs (www.wired.com/

autopia/2013/07/open-source-airplane-design). People might be able to build a personal plane for as little as US\$15,000. On the other end of the cost scale, my favorite is a small \$15 solar controller kit that I've built several times for different uses (www.ghurd.info). All of these Web sources let people build what they need easily and much more cheaply than they could obtain the products from commercial vendors. Given that this is probably only the beginning of this trend, a new economy will likely emerge. But there's more than just know-how and kits on the Web already. The Internet of Things is about to take on a whole new meaning.

Print It Yourself

Consider home 3D printers. They're pretty much here (<http://detroit.cbslocal.com/2013/07/29/mtu-study-3d-printing-will-reach-the-home-soon/>). And an increasing number of open source designs are available on the Web. Search, download, and print what you need. The Web is no longer just for information. Data can be more than useful design information or even money: now data can be actual objects. You could even print your bitcoins so that data becomes physical currency. Not only that, but you can generate your own designs with a point-and-shoot 3D camera (<http://hothardware.com/News/Fuel3D-Affordable-PointandShoot-3D-Scanner-To-Complement-Your-3D-Printer-Now-on-Kickstarter/>). Talk about changing everything. You want cheap household goods (www.thingiverse.com/thingiverse/collections/household)? Spend the cash for this equipment and start saving within the year – especially if you share the cost with neighbors. There goes Walmart.

This is all about novel uses of the Internet (mostly the Web) enabling people to do things for themselves instead of depending on others'

products and services. It's a continuation of the trend that started when we fired our secretaries and wrote our own letters with word processing software on our computers. But the Internet is dramatically increasing our capabilities every few years.

Upon request, I wrote a "vision" piece in this space in 2010³ predicting that most people would be self-employed by 2015 and would be empowered by new Internet applications that let them not only better connect but be better coordinated for complex but perhaps short-lived tasks. I still believe that self-employment is the trend, and the only reason most still have salaries is because of the strange system of healthcare insurance we have in the US. This is but one trend where the Internet empowers people to do for themselves.

Yes, there are disadvantages, as we've learned from the NSA spying stories. However, these technologies can be defeated by others. I immodestly draw your attention to a piece I recently published in *The Economist* that shows how whistleblowers can escape detection when furnishing newspapers with sensitive documents.⁴

Our vision of America is frequently one of a consumer-driven economy based on malls and goods with short lifespans. The Internet has been heavily used by this economy. It supports Google, which in turn is supporting DIY. This is the "old economy" supporting the new. There might always be malls, as long as energy is cheap, but for some substantial segment of the population, things are changing.

Want to build a solar photovoltaic system, a garden, a house, an airplane, or an electric car? The plans are out there, as is the advice from user forums. If you're not that ambitious,

maybe you'll just want to print your kitchenware on your home 3D printer. And this is an accelerating trend. When we look back in, say, 20 years, we'll see that this was the beginning of the Do It Yourself Age. □

References

1. C. Petrie, "The Edge of E-Cash," *IEEE Internet Computing*, vol. 1, no. 6, 1997, pp. 4–5.
2. *Virtual Currency Schemes*, European Central Bank, Oct. 2012; www.ecb.europa.eu/pub/pdf/other/virtualcurrencyschemes201210en.pdf.
3. C. Petrie, "Plenty of Room Outside the Firm," *IEEE Internet Computing*, vol. 14, no. 1, 2010, pp. 92–96; <http://www.cdr.stanford.edu/~petrie/online/peer2peer/vision2010.pdf>.
4. C. Petrie, "How to Blow Whistles Securely: Just AdLeaks," *The Economist*, 23 July 2013; www.economist.com/node/21580377.

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Toward Smart Machine Tools in Taiwan

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Tzuo-Liang Luo and Chien-Chih Liao, *Industrial Technology Research Institute, Taiwan*

For decades, machine tools have been widely used to manufacture parts for various industries—including the automobile, aerospace, national defense, machinery, modeling, electronics, and generator industries. Now, emerging high-tech industries, such as the semiconductor and thin-film-transistor (TFT) LCD industries, are starting to use machine tools as well to complete parts of the manufacturing process. Furthermore, some industrialized countries are using the output value of machine tools to measure and evaluate their national industrial strength and competence. In 2013, the global output value of machine tools reached US\$68.6 billion.¹

Here, we focus on the machine tools industry in Taiwan. The industry, one of the Taiwan's most important industries, has evolved over the last 60 years, transitioning from traditional three-axis machines to aerospace-precision machinery. In reviewing this evolution, we look at how the Taiwan Industrial Technology Research Institute (ITRI), with research support from academia, collaborated with

Taiwan manufacturers in the aerospace field to overcome various technical and marketing-related challenges.

Machine Tools in Taiwan

According to an investigative report from the Industrial Economics and Knowledge Center on the machine tool industry in Taiwan,² 78 percent of the products developed—mainly general-purpose machines—are being exported. The analysis of the industry's productivity level showed that the industry primarily focused on medium and low-end markets, including those of three-axis and lower-level machines. Therefore, the production precision and stability were low compared to what leading foreign manufacturers offered. Furthermore, because of the lower technical threshold, this market segment is highly competitive with lower profit margins and less potential for value-added products.

Technical Challenges

Taiwan's two main competitors for machine tool development are Mainland China and South Korea, both of which have made significant

progress in machine tool technology in recent years.³ Leading manufacturers in Japan and Europe also continue to achieve rising output value from machine tools, with major profits coming from high-end machines (three-axis machines and more advanced machines), especially those for manufacturing parts with aerospace precision.³

Aerospace elements require specific manufacturing procedures, which have longer process times and more precise cutting requirements than procedures found in other industries. Machine tools are thus required to clearly define the needed specifications and technical strategies used to manufacture specific aerospace elements. The integrated development of such highly competitive aerospace-level five-axis machine tools must rely on scientific and data-driven methods to obtain important reference information for every decision-making procedure.

Based on the recent trend in international machine tool development and the pursuit of mechanical precision and structural rigidity, the development of control software (that is, soft power) has

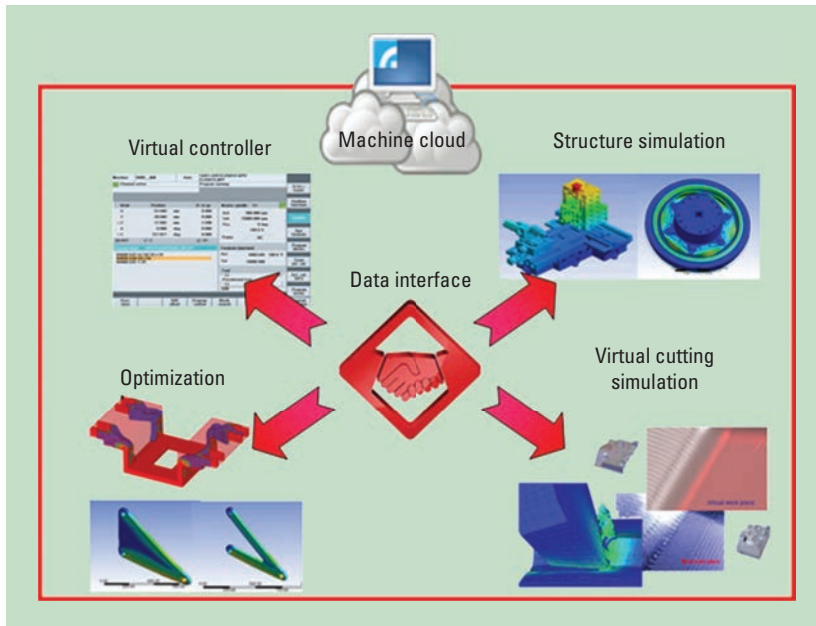


Figure 1. A system framework for machine tool development.² The virtual machine tool-design platform leverages cloud computing.

become the new focus of competitors in the machine tool industry. Intelligent machine tools have become particularly important, given the high costs, extended working periods, and multi-axis composite machine manufacturing process required for aerospace elements.

Taiwan's machine tools industry, in trying to improve its multi-axis processing technology, found insufficient software development to be its main bottleneck.

Marketing Challenges

Another issue was that the marketing strategies of Taiwan's machine tool industry mainly relied on participating in international machine-tool shows and using traditional media, such as video and direct mail advertising instructional materials. To enhance the competitive marketing strength of machine tools, Taiwan realized it needed to introduce cutting-edge 3D demonstrations and interactive presence technologies.

Since the proposal of Speed Up Robust Feature (SURF) technology

in 2006, markerless augmented reality (AR) techniques have been successfully developed.⁴ The development of AR presents two advantages. First, users can naturally interact with both real and virtual areas at any time and place, with enhanced sensory stimuli and enriched context that extends the original environment. Second, AR can be fused into real-life practices and combined with business strategies to achieve an integrative application of technical entertainment and business promotion.

Machine Tool Technologies

To address these technical and marketing-related challenges, ITRI, with research support from the University of British Columbia and Shih Chien University, collaborated with Taiwan manufacturers in the aerospace industry to develop universal technology solutions.

Cloud-Based Virtual Machine Tools

To solve key technical issues in the development of aerospace-level

machine tools, and to achieve machine designs that can quickly adapt to the requirements of aerospace manufacturing, ITRI worked with the University of British Columbia. Together, they developed a system framework for machine tool development (see Figure 1). Previous design experience and related data are stored in cloud devices and combined with virtual machine (VM) tool design procedures to support a high-efficiency cutting process. Furthermore, the actual manufacturing procedure of aerospace elements is analyzed to guide technical development in every subproject of the integrated research and development of high-end aerospace machine tools.

The technology integrates the topology-structure-generation technique from ITRI and the cutting simulation technique from the Manufacturing Automation Laboratory (MAL) at the University of British Columbia. The core techniques for machine tool development include spindle design optimization, virtual cutting procedure simulation, and optimal topology structure generation.

Spindle design optimization. To analyze the machine tool spindle design, this technique can analyze static deformation, modal shape, as well as the velocity and acceleration of the spindle under stress. It also provides optimization analysis for spindle design and can be used as a diagnostic tool for developed spindles.

Virtual cutting procedure simulation. This technique can directly help the machine tool user quickly adjust the machine. The core technology is a cutting stability analytical function (using a cutting stability lobe), which can predict the optimal maximum cutting depth, feed velocity, and spindle speed, thereby improving cutting

efficiency. In addition, apart from analyzing machine-cutting data, the technique can perform various simulation and prediction functions for cutting states.

Optimal topology structure generation. This technique enables the automatic calculation of optimal structure shapes. The arrangement of bars is calculated by computer simulation analysis, which can effectively reduce the effects of subjective factors, obtain high-efficiency structure optimization design, and achieve excellent performance enhancement.

Machine Tool AR Demonstration

In large-volume manufacturing, machine tools need a certain amount of storage space for some features to operate appropriately. Clients can only view machine tools from a fixed angle in a video feed, which isn't ideal for selling machine tools.

The Department of Intelligent Machine Tool Technology Center of ITRI collaborated with the Department of Information Technology and Management at Shih Chien University and developed the Machine Tools Augmented Reality (MTAR) system (see Figure 2). Based on the markerless AR technique, the system can integrate real and virtual spaces using different platforms, such as a web-cam, smartphone, or tablet device, without extra power or demonstration space. As such, clients can project the virtual machine tool to a real field and quickly learn the features and characteristics of the machine from different angles and aspects.

AR demonstration technology can also provide reference information for factory area planning in the machine tool industry, creating new opportunities for demonstration and marketing.

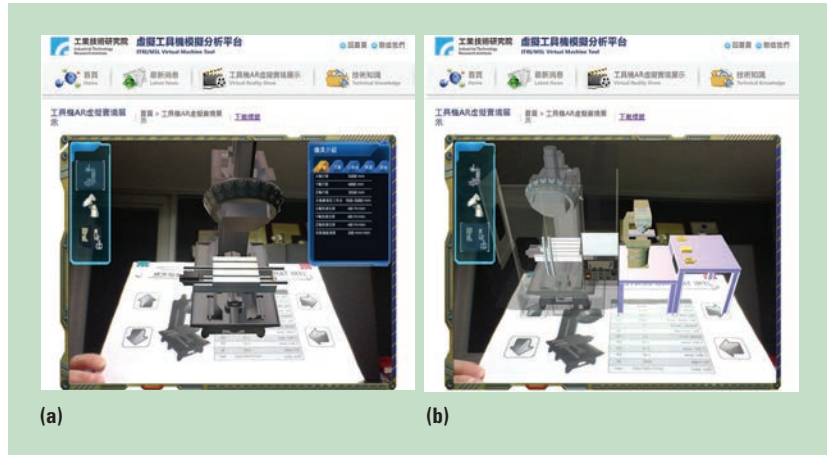


Figure 2. The Machine Tools Augmented Reality (MTAR) system: (a) a screenshot of the Web-based system, and (b) a simulation execution screenshot of a machine arm and machine tools.

In the future, Taiwan's machine tool industry will integrate multidomain technology to improve product design and production capacity. It also plans to develop system integration, testing, and verification technology and increase innovative manufacturing value. Finally, it hopes to create technical service capabilities and build cloud services platform for enhancing global sales and service for best solutions of overall global machine tools.

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References

1. "The World Machine Tool and Consumption Survey 2013," Gardner Research, 2013.
2. T.L. Luo et al., "Innovative Virtual Machine Tool Design," *Proc. 16th Int'l Conf. Machine Design and Production*, 2014, pp. 804–809.
3. S.T. Huang, "2013 Global Machine Tool Production Report," *Machine Tool & Accessory Magazine*, vol. 8, no. 4, 2014, pp. 50–55.
4. H. Bay, T. Tuytelaars, and L. Van Gool, "Surf: Speeded Up Robust

Features," *Proc. 9th Euro. Conf. Computer Vision*, 2006, pp. 404–417.

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by Douglass Post
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Product Development with Virtual Prototypes

For most research-funding organizations, computational engineering is a study area in academic engineering departments, and is often somewhat indistinguishable from highly applied physics, chemistry, and biology research. I'm going to address a different kind of computational engineering that is focused on the development, manufacture, and deployment of innovative, complex technical products such as computers, electronics, ships, and airplanes. Much of the current US prosperity is due to its lead in product innovation, especially in these types of high-technology products. Computing played an important role in establishing that lead and its role in sustaining the lead is growing. The construction and analysis of virtual prototypes with physics-based performance software tools utilizing high-performance computers offers US industries and government an opportunity to reduce the time, cost, and risks of developing, producing, and deploying complex, innovative technical products. The productivity gain from the use of virtual prototypes analyzed with physics-based performance prediction tools is a potential game changer for product development.

The potential game-changing effects of virtual prototyping can be understood within the context of the traditional systems engineering approach to product development and production (see Figure 1).

The System Lifecycle Model

Concept development includes formulating and defining a system concept that meets a specific need.¹ Engineering development is turning the system concept into an engineering design that meets the need within cost and schedule constraints. Post-development includes manufacturing, deploying, and sustaining the system. The design of innovative new products require extrapolation of existing designs. These extrapolations are based on experience with existing systems; expert judgment; and "rules of thumb" and other simple analyses. Increasing the level of innovation increases the level of extrapolation, and the associated risk that the extrapolation will include too many uncertainties. Validating the design of innovative complex systems (automobiles, airplanes, and so on) requires physical testing that can only occur late in the process, chiefly in the engineering design/integration and evaluation phases, when partial and full-scale physical prototypes become available.

This product development paradigm traces its origin to the industrial revolution, if not before. Several centuries ago a simple version of a product (such as a steam engine) would be designed, constructed, and tested. The failures observed during testing would be analyzed,

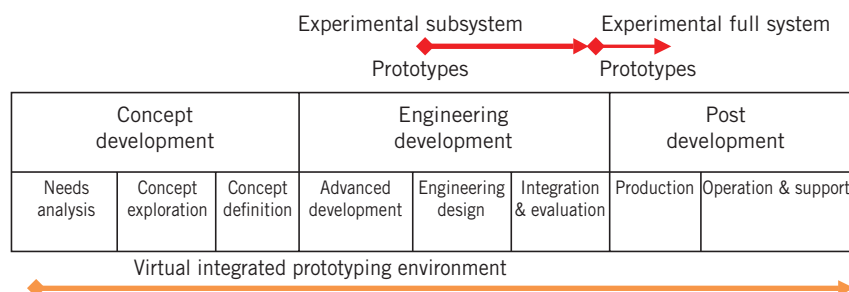


Figure 1. System lifecycle model for product development and production.¹

and the “design, build, test, fix” steps iterated until an acceptable design and product emerged, or funds and time ran out. As products become more complex and the level of extrapolation increases, this “design, build, test, fix” paradigm requires more iterations and time to converge. In addition, it becomes more difficult, if not impossible, to change the product requirements to respond to new needs, because the increased time and money required for rework to address new requirements and correct shortcomings are prohibitive.

Moving to Virtual Prototyping

An alternative approach is emerging based on the use of “virtual” rather than physical prototypes. The virtual prototypes are digital representations of the product’s geometry and attributes. High-fidelity physics-based software tools are used to predict the product model’s performance to supplement or replace physical tests. Extrapolating from present experience using the universally valid laws of physics is proving to be a much better way to design innovative products. The design team can develop optimized designs instantiated as virtual prototypes, then test them to identify design flaws and make necessary design changes well before metal has been cut. In addition, changes in operational requirements and product innovations can more quickly be assessed and design changes effected. The virtual prototype paradigm can be applied at all stages of the product development process, from requirements definition to sustainment. The product model and the design analysis information can propagate as digital information through the entire product development process. Transferring product descriptions as digital information can also reduce the product development time and improve the quality of the communication of technical information. It has the additional benefit of minimizing the large number of documents that traditionally must be written and read when design and production handoffs occur between different organizations involved in the product development process.

Around 2003, Goodyear Tire implemented this paradigm, and over the course of several years, they were able to reduce their time to market by a factor of four, increase the number of new products from 10/year to 60/year, and reduce product development costs by 60 percent.² The Goodyear high-fidelity physics-based tools had sufficient accuracy that Goodyear ultimately dispensed with all of their physical tests except for a test of the finished product conducted concurrently with initial manufacturing. Occasionally, the final test revealed a design problem, but not often enough to negate the huge market advantage of reducing the time to market by a factor of four.³ Many other companies have implemented this paradigm,⁴ but it’s generally difficult to get hard information on their successes. Virtual prototyping with physics-based prediction tools provides a competitive advantage and is considered a trade secret. The US nuclear weapons design laboratories have utilized this paradigm since the beginning of the Manhattan Project. It’s not common knowledge, though, because there is no reason for them to advertise the effectiveness of physics-based computational engineering.⁵

The power of this approach was recognized early by the civil engineering community. In the 1970s, engineers used engineering applications on workstations to design buildings and complete the interior layout (electrical, plumbing, heating and air conditioning, windows and doors, structural supports, and so on). The laws of physics are captured in the standard building codes. Structural analysis with tools like NASA Structure Analysis (Nastran; see <http://en.wikipedia.org/wiki/Nastran>) followed. There are now multi-physics commercial tools such as MatLab (www.mathworks.com/products/matlab), Ansys (www.ansys.com), and Comsol (www.comsol.com), that run on workstations and can handle moderate-size problems that integrate several different physics effects. The microprocessor industry has used the virtual prototype paradigm since the mid-1970s when the Simulation Program with Integrated Circuit Emphasis (SPICE) code appeared.⁶ Today, descendants of SPICE are used to construct and analyze models for all new integrated circuits.⁷ The most ambitious multi-physics analyses require supercomputers due to the sheer number of calculations required.

At present, the computing power available for moderate- to larger-scale engineering analysis is approximately 10 to 1,000 TeraFloating Point Operations (TFLOP)/s

(Tera = 10^{12}). It's routine to use 10 TFLOP/s or more for a few hours to a week or more to assess challenging engineering problems. The US government proposes to build an exascale computer (10^{18} FLOP/s), and the most powerful computer in the world today (in China) runs at approximately 30 PetaFLOP/s (Peta = 10^{15}).

Computing power in the 100 to 10,000 TFLOP/s range is a breakthrough for computational engineering in terms of analysis capability. With such powerful computers, engineers can use codes that are numerically accurate, include the most important physics effects, can handle large problems that span a wide spatial and temporal range (such as a complete airplane or ship), are well validated, and run sufficiently fast that the engineers can obtain reliable decision data in a timely fashion. Industry is beginning to use high-power computers, as well. Recently, General Motors (GM) opened a \$130 million supercomputer facility to study vehicle crashes and minimize air drag. For GM, it's faster and cheaper to use physics-based analysis employing virtual prototypes with high-performance computers than to construct and destructively test a large number of vehicles.

Learning from Goodyear

The Goodyear story provides a fairly complete picture of the ecosystem that is required for virtual prototyping to be effective:

1. sponsors (for example, corporate marketing, sales, and engineering leadership) who need product development decision data and are willing to pay for it;
2. subject matter experts (such as tire designers) to do the analysis and advise the decision makers;
3. high-performance computers (computing requires computers);
4. high-speed networks to connect the design engineers to the supercomputers;
5. an experimental test program to provide validation data for the software tools; and
6. physics-based software applications that can provide accurate performance predictions of the product design.

Much of the ecosystem is generic—it can be used for many different applications. However, the software applications pose the most difficult challenges to develop and support. They are generally different for each specific class of products and are costly to develop (10–15 experts for approximately 10 years).⁸ For many commercial systems, commercial software tools may be adequate (for example, Ansys), so that the lead time is reduced. However, the cost of licenses should be included in the economic analysis of the value of the virtual prototyping approach.

The Goodyear story also illustrates many important advantages and challenges of virtual prototyping. Goodyear was able to dramatically improve their product-development process (as mentioned before, by a factor of four reduction in time to market, and then also a six-fold increase in the number of new products each year), but it took 10 years to build the software applications and the necessary computational ecosystem. The company only undertook the risk of adopting virtual prototyping when they were facing severe financial challenges, and had no other choice because the tried and true “design, build, test, fix” process wasn't fast enough to develop new products fast enough to keep the company competitive.

Another lesson is that Goodyear initially only changed its design process. It kept the “design, build, test, fix” product-development process, including all the physical tests. The virtual prototype designs (tested with internally developed software tools that were developed with help from the Sandia National Laboratory) passed the tests so that redesign and rework and the associated time and cost growth was much less. As the process matured, the physical tests were recognized to be redundant and were dropped by the product development organization since the virtual testing caught the major design flaws early when they could be easily fixed. After a few years, Goodyear went into production and physical

testing at the same time. Occasionally, the test turned up a problem. Goodyear analyzed the test results and fixed the code. They continued relying on virtual prototype designs because the productivity gains from the use of virtual prototypes far exceeded the costs of an occasional hiccup in the product development process.

Today, the US faces intense international economic and military competition from our allies and foes. Although US industry is still competitive and remains the leader in product innovation, its lead over the rest of world could vanish in a few years. On the military side, the US military advantage is due to its superior military technology and its large military budgets. However, the cost of new weapon systems and the time to develop them are growing dramatically. The plethora of recent news articles on the Joint Strike Fighter (JSF) and the Littoral Combat Ship (LCS) demonstrate the product-development challenges facing the US Department of Defense (DoD). The Department of Defense is beginning to experiment with the use of virtual prototyping to reduce acquisition time, cost, and risks. The DoD High-Performance Computing Modernization Program CREATE program (www.hpc.mil) is having very positive results with virtual prototyping. The use of virtual prototyping by private industry is rapidly growing. However, our foreign competitors are also beginning to adopt computational engineering. This offers them the ability to leapfrog over organizations that are relying on the traditional “design, build, physical test, fix” paradigm. Virtual prototypes offer the US great potential for keeping its competitive edge, but only if the US aggressively adopts their use. If it doesn’t, it runs the risk of being overtaken and passed in the global innovation race. ■

References

1. A. Kossiakoff and W. Sweet, *Systems Engineering Principles and Practice*, John Wiley and Sons, 2003.
2. L.K. Miller, “Simulation-Based Engineering for Industrial Competitive Advantage,” *Computing in Science & Eng.*, vol. 12, no. 3, 2003, pp. 14–21.
3. Goodyear Tire, *Goodyear 2009 Ann. Report*, investor report, 2009; <http://investor.goodyear.com/annuals.cfm>.
4. Council on Competitiveness, *Council on Competitiveness: HPC Success Stories*, 2010; www.compete.org/about-us/initiatives/hpc/success%20stories.
5. S. Francis, *Warhead Politics, Livermore and the Competitive System of Nuclear Weapon Design*, Dept. of Political Science, Massachusetts Inst. of Technology, 1995.
6. L.W. Nagel and D.O. Pederson, *SPICE (Simulation Program with Integrated Circuit Emphasis)*, memorandum, Univ. of California, Berkeley, Electronics Research Laboratory, 1973.
7. R.P. Colwell, *The Pentium Chronicles: The People, Passion, and Politics Behind Intel's Landmark Chips*, Wiley/IEEE Computer Society, 2005.
8. R. Kendall et al., *Case Study of the Hawk Code Project*, Los Alamos Nat'l Lab., 2005; <http://library.lanl.gov/cgi-bin/getfile?LA-UR-05-9011.pdf>.

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Beyond *Minecraft* *Facilitating Computational Thinking through Modeling and Programming in 3D*

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The popularity with children of 3D design environments such as *Minecraft* has revealed previously untapped interests in modeling worlds, regardless of whether they're real or fantasy. As processors and graphics engines have improved, so have opportunities to consider how 3D programming environments might engage a significant proportion of the next generation of students in computer programming. We believe that when students have access to programming environments that can model interesting social, natural, and imagined phenomena, they'll more likely see programming as an essential skill for rendering their worlds.

Programming in three dimensions is engaging to young people who have regular experiences with 3D virtual worlds. Their experiences with high-quality 3D media—in movies, television, and gaming—have raised their expectations for computer-based design experiences. It's also important to consider design as an entrée to computer programming because representing agent behavior in 3D is an activity in which design and programming are seamless. When children focus primarily on modeling the world and related agent interactions, they find that programming is just part of the design process rather than an arbitrary skill set requiring the completion of a class.

As part of a large-scale study of computer science education based on the Scalable Game Design curriculum, we've introduced more than 12,000 students and more than 200 teachers to 2D and 3D end-user programming environments to create games and STEM (science, technology, engineering, and mathematics) simulations. AgentSheets, our 2D environment, has been used for years in computer science education and computational-science simu-

lations. AgentCubes, a much more recent 3D environment, can turn AgentSheets projects into 3D projects through a process we call incremental 3D.¹

On the surface, 3D sounds much more appealing than 2D, but what are the benefits of creating and using 3D? Here, we discuss our experiences with the differences between 2D and 3D as they relate to three concepts connecting computer graphics to computer science education: ownership, spatial thinking, and syntonicity.

Ownership

We've found ownership, and the related notion of creativity, important to motivation. Motivation, in turn, is a key to computer science education. Students who believe programming is difficult and boring won't likely engage in computing careers.

In spite of its simplicity, AgentSheets' 2D depiction editor was a key factor in getting students excited about computing by first having them draw objects they can use as characters in their worlds. Although middle-school students have developed higher expectations for computer graphics by playing sophisticatedly rendered 3D games such as *Halo 3*, to our surprise they still enjoyed AgentSheets' simple 2D depictions. As one student put it, "I like it because I made it." More generally, we found such ownership essential to broaden student participation.²

The big appeal of a simple 2D depiction editor is that it has a low threshold for engaging in creative endeavors. Typically, the same thing can't be said about 3D creativity, which is often perceived as far more arduous. Tools to create 3D objects from scratch, such as Maya 3D or Blender, have intricate interfaces with steep learning curves and are well suited for professional 3D modelers but much less so for end-user designers. Most educational

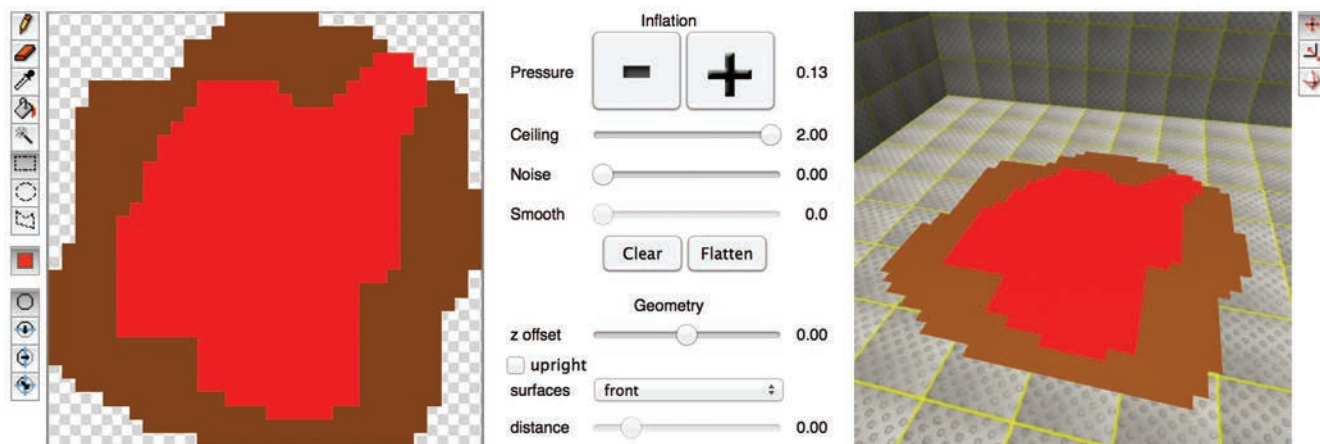


Figure 1. The Inflatable Icons editor. A user drew a top-down view of a volcano as an irregular brown shape with red lava inside (see the left image). After placing the volcano in the 3D editing environment (see the right image), the user applied inflation and other operations to create the 3D version in Figure 2.

3D programming environments minimize 3D modeling's obscurities by offering limited 3D mechanisms. With Alice, for instance, most users don't create their own 3D models but select 3D objects from a palette. In *Minecraft*, users assemble objects consisting of large numbers of boxes.

In contrast, we aimed to preserve the rapid-sketching spirit of 2D icon editing. So, we developed the Inflatable Icons approach. To create simple 3D shapes incrementally from scratch, users draw a 2D image and inflate it into a 3D image (see Figures 1 and 2). This paint-then-model approach differs radically from most other model-then-paint end-user 3D-modeling approaches.

In AgentCubes, with little more than a minute of instruction, students can build 3D models (see Figure 3). Of course, these shapes are aimed not at Pixar animators but at casual 3D modelers. Teacher and student feedback confirms that creating these 3D shapes is highly motivational. In some cases, teachers "complained" that students were so excited to create 3D shapes that they spent too much time with 3D modeling.

Spatial Thinking

If the main objective is for students to learn about computational thinking, educators must carefully consider the benefits and costs of employing 3D technology. Inflatable Icons can make creation of 3D models accessible even to young children, but creating a 3D game or simulation involves more than just creating individual shapes. Compared to 2D authoring, assembling 3D shapes in 3D worlds places heavier demands on student reasoning. Students must be able to understand how to control cameras, how to think in three dimensions by stacking objects to build composite structures, or even how to use layers to create more sophisticated worlds.

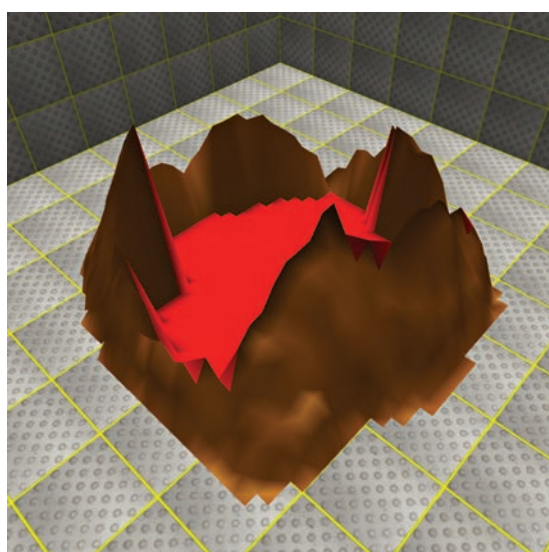


Figure 2. With Inflatable Icons, the user inflated the shape of the volcano in Figure 1, added noise to simulate a rocky surface, selected the lava, removed the noise from the lava, and pushed down the ceiling to flatten the lava's surface.

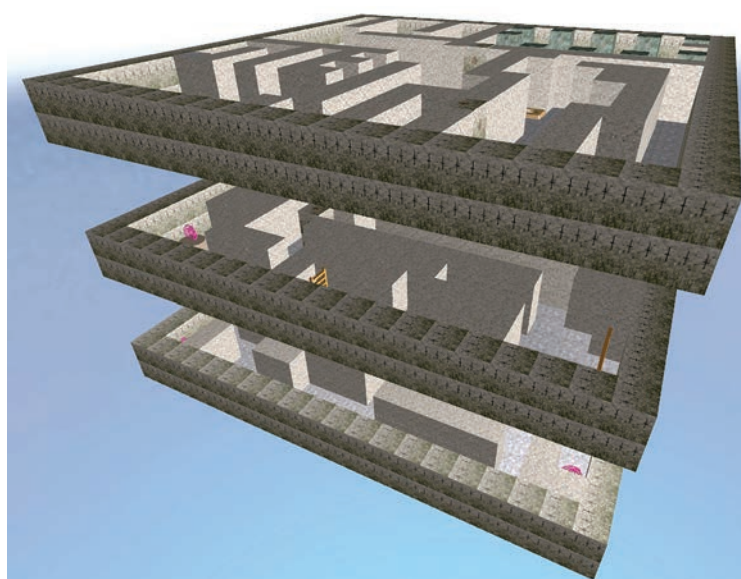


Figure 3. Using AgentCubes, a middle-school student created and programmed a complex multilayered game.

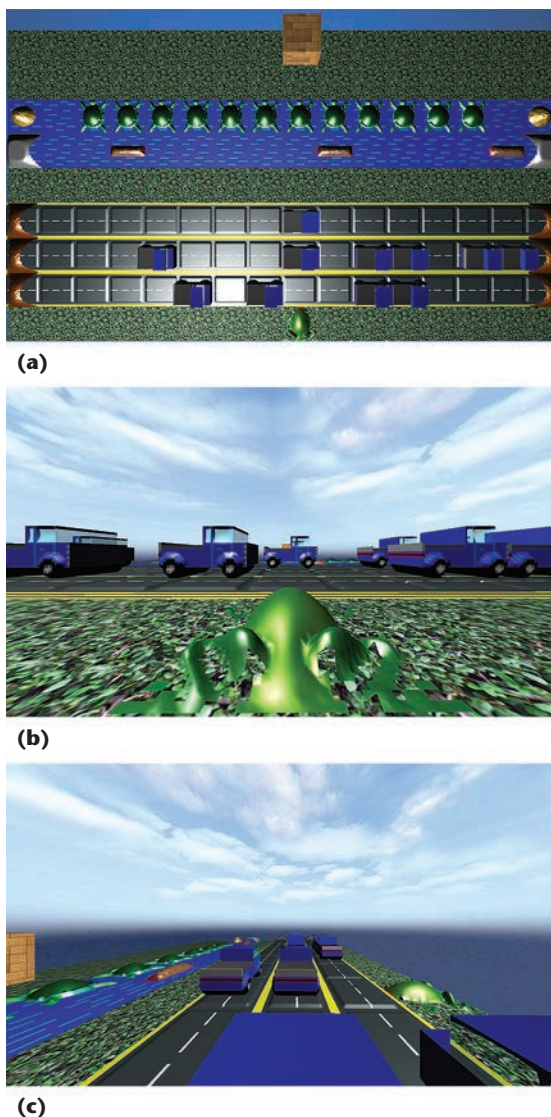


Figure 4. In a syntonic perspective, the user assumes the viewpoint of an object in the virtual world. (a) A (nonsyntonic) bird's-eye perspective. (b) A syntonic frog perspective. (c) A syntonic car perspective.

However, we found little evidence that students struggle with 3D composition and camera control. It's certainly possible to flip worlds around and to get the camera in an awkward position in ways that wouldn't have occurred in a 2D world. However, this rarely happened. In many cases, these apparent 3D-thinking skills could have resulted from students having played advanced 3D games or 3D construction-oriented games such as *Minecraft*.

Sometimes, 3D design is actually simpler than 2D design. One such case is debugging using AgentCubes. For instance, when creating a *Frogger*-like game, students generate trucks that move on a road and could collide with the frog. They frequently forget to program the trucks to disappear at the end of the road, often resulting in trucks piling on top of each other.

In the 2D environment, this stacking of trucks goes unnoticed; from a bird's-eye perspective, there's only one truck left at the end of the road. When the game runs for a longer period, thousands of trucks might be stacked at the end of the road. This results in the game slowing significantly and possibly crashing.

In the 3D version, just two stacked trucks will get the student's attention, prompting the realization that the rule to remove the trucks must be missing. Design in 3D requires students to think of their worlds in ways that integrate troubleshooting and spatial visualization, which are different aspects of computational thinking.

Syntonicity

The final concept comes from the psychology of programming. Early on, Seymour Papert speculated that humans' ability to project themselves onto objects—essentially becoming the objects—would help them overcome otherwise difficult programming challenges.³ The ability to comprehend and even predict behaviors is called *body syntonicity*.

Papert and his colleagues developed the famous Logo robotic turtle, which children could program through simple instructions that made it move forward and turn. Later, Papert and his colleagues replaced the physical turtle with a simulated version. The Logo programming language eventually incorporated syntonicity, which added a psychological aspect to the otherwise technical framework of computation. Through syntonicity, children could explore interactions that were difficult to understand by formulating first-person questions, such as "If I'm this turtle and I turned 90 degrees left, what would I see?"

Ample evidence exists that programmers naturally employ syntonic notions. For instance, programmers say something like, "How can the compiler do this to me?" when they're actually referring to the program they wrote. However, it's less clear what syntonicity's educational benefits are.

To explore this, we created a syntonic version of the Visual AgentTalk programming language, which is part of AgentSheets and AgentCubes. This syntonic version originally had elaborate commands using language suggesting syntonic interpretations. For instance, instead of a "move (direction)" action, there was an "I move to the left" action. That is, instead of the programmer just thinking that some object is moving, the language suggested that it's "I" who is moving to the left.

Although children with no programming background liked the language, more experienced users rejected the general increase in verbosity. So, we

compromised. We kept the short command names for the actual visual-programming language. In addition, we offered mechanisms such as explanation buttons and tool tips to provide syntonic versions of the commands, in case users needed help interpreting the commands' functions.

With 3D worlds, you can go a significant step further. You can map the psychological perspective of becoming an object onto a user interface that lets programmers select any object in a complex world and put that object into a first-person perspective. If the object moves or turns, the camera adjusts accordingly.

In this way, users can experience any game or simulation in AgentCubes from the perspective of any of its objects (see Figure 4). Many students have employed and enjoyed this feature, but we have no evidence whether students are actually assuming syntonic perspectives. We also don't know whether this feature really helps overcome challenges more easily than would be possible in 2D.

However, we've connected this syntonic perspective explicitly with our programming environment through conversational programming.⁴ This approach has proven useful for semantic-programming support. When a user selects an object in AgentCubes, the programing environment immediately shows that object's code. It also runs that code one step into the future and annotates the program to show what the object in its current state will do.

As you can see, 3D computer graphics are highly relevant to computer science education for reasons beyond motivation. In our experience, to receive 3D graphics' full benefits for computer science education, novel programming environments should support authoring approaches that incorporate 3D rapid sketching and should explore ways to connect 3D navigation with semantic support for programming.

AgentCubes Online, which employs HTML5 and WebGL (Web Graphics Library), is the first browser-based 3D-modeling and visual-programming tool of its kind. Over 250,000 students worldwide have used it as one of the Hour of Code tutorials; you can play with it at <http://hourofcode.com/ac>. ■

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References

1. A. Ioannidou, A. Repenning, and D.C. Webb, "AgentCubes: Incremental 3D End-User Development," *J. Visual Languages and Computing*, vol. 20, no. 4, 2009, pp. 236–251.
2. D.C. Webb, A. Repenning, and K.H. Koh, "Toward an Emergent Theory of Broadening Participation in Computer Science Education," *Proc. 43rd ACM Tech. Symp. Computer Science Education*, 2012, pp. 173–178.
3. S. Papert, *Mindstorms: Children, Computers, and Powerful Ideas*, 2nd ed., Basic Books, 1993.
4. A. Repenning, "Conversational Programming: Exploring Interactive Program Analysis," *Proc. 2013 ACM Int'l Symp. New Ideas, New Paradigms, and Reflections on Programming & Software*, 2013, pp. 63–74.

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Visions for Augmented Cultural Heritage Experience

Right from the beginning, museums and, more generally, cultural heritage settings have been planned with a mixture of social, political, and economic motivations. For example, the foundation of the Uffizi Gallery in Florence, Italy, the first museum in the world established in 1591, explicitly followed this course. It was planned to exhibit paintings and sculptures collected by the Medici family, with the twofold goal of educating people in art and showcasing the family's political power. The Uffizi Gallery also hosted artisan laboratories of goldsmiths and miniaturists and, as a result, became the working nucleus of Florentine artistic handicraft economy.

In other respects, museum visitor experiences differ from person to person, from cognitive to affective experiences. Despite the range of interests and experiential diversity, for a long time cultural curators have privileged the cognitive dimension rather than the affective. Museum exhibits, cultural heritage site layouts, and guides have been designed to transfer information in a meaningful way to a sort of "standard visitor," following the transmissive learning model of educational programs.¹

Progress in information technology has provided us with the opportunity to improve both the quantity and personalization of cultural information. More importantly, we can now experiment with the application of the new theories of social constructivism and experiential education that favor action, interaction, immersive spaces, and engagement. Multimedia documents, augmented reality, and Web-mediated information have expanded the types of data at our disposal. In addition, the availability of mobile devices helps us move another step toward augmented and personalized visits. Such devices allow us to adapt content in mobile guides to each individual's cognitive needs and interests and provide the means for users to interact with content. (See the "Notable Project" sidebar for work in this area.)

Technologies for Augmented Experience

Web 2.0 has made social connectivity, sentiment analysis, user profiling, and personalization popular and has promised to reduce the "affective gap" in the visitor experience.

New real-world applications have reconceptualized augmentation of cultural experience as a cultural and aesthetic practice rather than a technology. Greater engagement for the visitors is obtained by analyzing their interests in social profiles, from the likes during previous visits and from the interests of the friends in their social network. Nevertheless, the improvements over the standard visitor approach are still far from satisfactory. There is the risk of statistical generalization because the analysis of habits from social activity typically discovers macro-interests that represent behaviors and interests of groups of people rather than individuals.

Bridging the affective gap by understanding the visitor's individual cognitive needs and interests and his or her situational affective state is still a challenge. Indeed, affective states largely depend on current emotional conditions and are difficult to predict. A main challenge therefore is to build time-varying visitor profiles that include the visitor's background and cultural basis (as a reference for the cognitive experience) and his or her contextual (to fit the momentary cognitive needs) and situational conditions (to fit the momentary affective status). We must also collect or detect this information as nonintrusively as possible without requesting annotations or explicit declarations. Computer vision can provide satisfactory answers to these challenges.

Envi-Vision and Ego-Vision for Augmented Experiences

Human vision is a powerful and natural medium for interacting with art. Recent neuro-aesthetic theories, from the seminal work of

Notable Projects

Here are a few notable early projects (among the many) that have explored new opportunities in this area:

- The PEACH project used sensor-originated location and orientation as well as visitor validations to provide new topics suggestions.²
- Several institutions have attempted to infer visitors' interests based on their positions detected using sensors and mobiles.^{3,4}
- The CHIP project provided recommendations derived from visitor interests, which they declare on the museum website and during their visit.⁵

■ Several museums, including the Smithsonian Museum in New York (<http://mashable.com/2013/11/21/smithsonian-museum-3d/>), the Powerhouse Museum in Sydney (<http://mashable.com/2011/09/14/high-tech-museums/>), the Cleveland Art Museum (<http://mashable.com/2013/01/25/cleveland-art-museum-gallery-one-touchscreen/>), have done experiments on improving visitor engagement using mobile systems.

Semir Zeki⁶ to the more recent studies of Eric Kandel,⁷ have assessed the strong connections between art and vision. Visitors see the artistic productions and construct their interpretation of the world according to their cultural experience.

Computer vision technology has appeared as a powerful artificial sense to complement human vision, by understanding both contextual and situational conditions of visitors and enabling a more complete cultural experience. Computer vision also has multiple advantages with respect to other technologies, from the implementation viewpoint. Camera sensors integrate seamlessly and nonintrusively and can thus exploit existing infrastructures. Deployment is highly scalable, from the personal to very large, covering a room, an entire exhibit, or even multiple networked sites. We therefore expect that blending computer vision technology in museums and cultural heritage settings can help to bridge the affective gap.

In general terms, *deployable computer vision systems* (by which we mean cameras, embedded vision devices, computing elements, and computer vision algorithms) can be classified into two broad categories: *envi-vision* and *ego-vision* systems. The former are fundamentally suited to provide an overview of the environment from an external viewpoint, and the latter are more appropriate for collecting information about the visitor's neighborhood from the individual viewpoint. Envi-vision systems include traditional vision systems for video surveillance, in a single or networked configuration, as well as new sensing devices such as multisensored

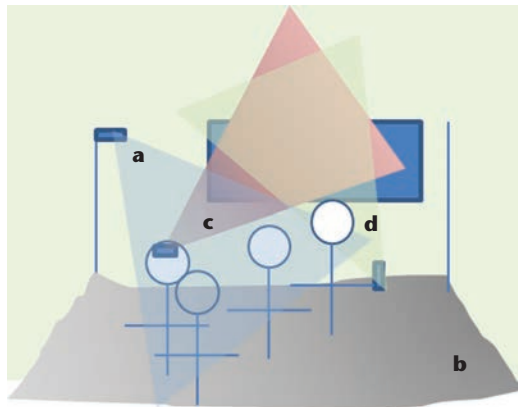


Figure 1. Deployable computer vision systems. *Envi-vision devices include (a) surveillance cameras and webcams and (b) sensing surfaces. Ego-vision devices include (c) glasses and wearable cameras and (d) smartphone cameras.*

surfaces. Ego-vision systems include solutions that utilize wearable cameras and mobile cameras in handheld devices. They exploit the technological advances of mobile and wearable technologies and are becoming increasingly popular as a result of the miniaturization of sensing devices and computing systems.

Envi-vision and ego-vision systems can play important complementary roles to augment cultural experiences (see Figure 1). Envi-vision systems can be employed to collect data useful for profiling during a visit (for example, by target detection and tracking, understanding individual and social behaviors, and crowd analysis) and to detect momentary conditions or unpredicted situations. They are therefore

Argos Myth and Ego-Vision

People wearing multiple cameras with ego-vision capabilities might recall the Greek myth of Argos *Panoptes*. Argos was a giant with 100 eyes commanded by Hera, queen of the gods, to guard the young nymph Io from Zeus' amorous attentions. Argos' eyes were located in almost every part of his body so he could see continuously everything around him at all times in any direction, making him a perfect guard. However, Zeus sent Hermes to rescue Io. Hermes put Argos to sleep by playing a sweet enchanting melody and liberated Io so she could join Zeus. Argos' 100 eyes were placed by Hera on the plumage of the peacock tail.



Figure A. Hermes kills Argos and rescues Io (transformed into a heifer). (Inv. No. IV 3729, Collection of Greek and Roman Antiquities, Courtesy of Kunsthistorisches Museum Vienna.)

well suited to deliver information that fits with contextual conditions. Although many problems are still open, envi-vision architectures are sufficiently mature for real-world deployment.

Ego-vision systems can help us to understand what visitors are observing or doing, focus their attention, and determine their degree of interest. Such systems can deliver information that fits the visitors' momentary expectations. Ego-vision systems also make it possible for the visitor to simultaneously observe objects or events in multiple directions, in addition to those visible with their eyes, and collect information from different viewpoints at the same time. (See the "Argos Myth and Ego-Vision" sidebar that recalls a story from Greek mythology.) This will improve awareness, safety, and their consciousness of the surroundings and nearby opportunities.

A Functional Taxonomy of Vision for Augmented Experience

We can identify the following four working modalities and related functions of computer vision systems (see Figure 2 and Table 1):

- *Seeing what your eyes cannot reach.* Envi-vision systems can extend human vision in space and time by providing views of remote locations as well as information from distant areas and past scenes. For example, vision systems mounted on drones can exploit birds-eye views and enable aerial visits that

are normally excluded from visitors' experiences.

- *Seeing what your eyes cannot see.* Both envi-vision and ego-vision systems with special cameras can work with thermal, infrared multispectral, ultra-resolution, and high frame rate and depth images and support different interpretations of cultural heritage assets. Such systems serve to augment human vision capabilities with different frequency ranges and perceptual capabilities. Envi-vision systems applied to sensing floors can interpret pressure images created by people walking over the floor and detect the visitors' flows, behaviors, and states. Interactive walls hiding infrared cameras can support seamless interaction with natural gestures.
- *Telling you what you are seeing.* Detecting landmarks and recognizing image details lets us redirect a visitor's attention to potentially interesting elements and extract information from the Web using content-based retrieval. This serves to enrich vision with semantic information. Smartphones can have this ego-vision capability, and envi-vision systems can also provide such information.
- *Seeing with more eyes.* Multiple cameras looking at different directions can augment the visitor experience, providing the equivalent

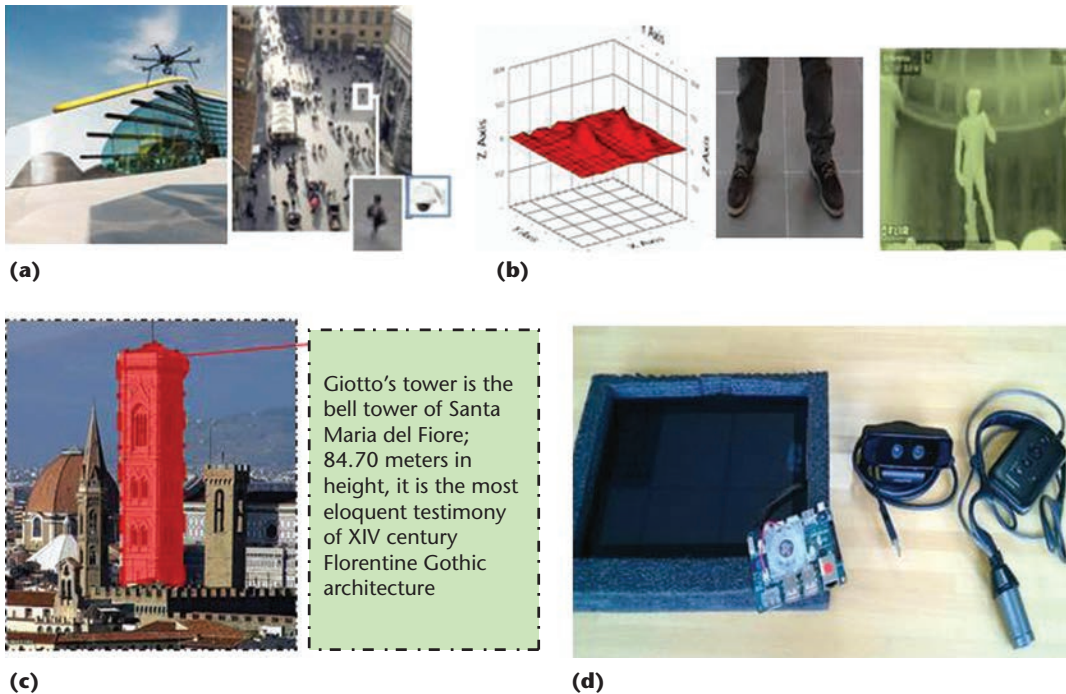


Figure 2. The functional taxonomy with examples of devices and systems. (a) For seeing what your eyes cannot reach (examples from drones from SAL Engineering Modena and surveillance cameras in Florence's Piazza Duomo), (b) for seeing what your eyes cannot see (pressure cameras in FLORIM spa devices and thermal cameras from FLIR sensors), (c) telling you what you are seeing (applications from an Android smartphone), and (d) for seeing with more eyes (wearable cameras from Panasonic (monocular) and Creative (stereo) and an embedded system from HandKernel).

of multiple simultaneously active eyes. Ego-vision devices such as cameras embedded in glasses, watches, earrings, or jackets lapels connected to miniaturized embedded computation machines will soon be able to provide such capabilities.

Implementing Augmented Experiences

Many of these functions are currently under development in projects recently launched by the Italian Ministry of University and Regional Governments in the framework of the Smart Cities and Communities initiatives. Here, we report on a few of the projects with which we are directly involved.

Mnemosyne

Mnemosyne is a three-year project (2011–2014) funded by the Regional Government of Tuscany and carried out by University of Florence. In the Mnemosyne system, visitors' interests are nonintrusively profiled using data collected by fixed cameras that observe visitors

and their paths in a museum hall (see Figure 3). A prototype installation is planned in early 2014 in the National Museum of Bargello in Florence.⁸ The system uses already installed cameras for surveillance and an interactive table that displays in-depth information on the artworks of interest to each visitor.

The computer vision technology is employed with a twofold goal: detecting the sites that most attract visitors and determining whether visitors are part of an individual or group visit. The system uses state-of-the-art detection and reidentification technology to detect visitors with multiple fixed camera views and assesses their presence within the sphere of influence of each artwork during the visit. A model is computed as a running average of the associated detections. To limit confusion between visitors with similar appearances across several hours of observation, we limit the association of detections to models that are active in a given temporal window. The profile is built on-the-fly when a visitor enters the interactive table area.

Table 1. A taxonomic view of working modalities and exploitable functions of computer vision systems for museums and cultural heritage settings.

Mode	Device type	Vision system	Functionality [†]				
			Context monitoring, tracking, individual-group behavior analysis	Contextual information, landmark detection, image object recognition	Situational information	Additional sensing and engagement	Multiple views
For seeing what your eyes cannot reach	Surveillance cameras	Envi-vision	***	***	**		*
	Webcams	Envi-vision	**	***	**		*
	Drones	Envi-vision	***				**
For seeing what your eyes cannot see	Special cameras	Ego-vision	**	*		***	
	Sensing floors	Envi-vision	**		*	***	
	Interactive walls	Envi-vision	*		**	***	
For telling you what your eyes are seeing	Mobile cameras	Ego-vision		***			**
	Fixed cameras	Envi-Vision		**	**		
For seeing with more eyes	Wearable cameras	Ego-vision		*	***	**	***

[†] The asterisks represent the degree of suitability in the application (* low, ** medium, and *** high).

FlorimAge

The FlorimAge project (2012–2014), carried out by Florim Spa and the University of Modena and Reggio Emilia, was funded by the Regional Government of Emilia Romagna to develop ceramic sensing surfaces capable recognizing user behaviors.⁹ The sensing floors are built with high-quality thin ceramic surfaces attached with a polymeric layer in a matrix of sensible points. User pressure images are processed to detect, track, and classify movements and behaviors of people passing over the floor.

The sensing floors can be used to count people, monitor their pauses, and profile their degree of attention. We also have experimented with new forms of behavior-based interactivity that are potentially interesting in cultural exhibits and museums.

Experiments at Brera Accademia delle Belle Arti in Milan have demonstrated the possibility of using body movements to explore a cultural heritage site using Google Street View data (see Figure 4).

Onna Social House

The Onna Social House is a project that was jointly developed by University of Florence and

Onna Onlus in 2012–2013 to preserve the memory of Onna, a small village near L’Aquila, destroyed by an earthquake in 2009. The installation consists of a central interactive rear-projected screen and two lateral screens used to display video clips and images. The visitors have a multisensorial experience by interacting with the satellite image of the village and receive video clips and pictures associated with places, people, and events or by switching between the views before and after the earthquake (see Figure 5). User gestures in front of the screen are captured by the infrared camera and then processed by the computer vision module that classifies the gestures as pointing, swiping, or shifting.¹⁰ Visitors can use natural gestures to display the informative content and are not required to wear any special device or equipment. The wall then reacts seamlessly like a book of village tales and images.

Tell_Me_Where

Tell_Me_Where is an ego-vision system designed by the University of Modena and Reggio Emilia to offer augmented experiences to visitors of the Enzo Ferrari Museum in Modena using smartphones and glass cameras.

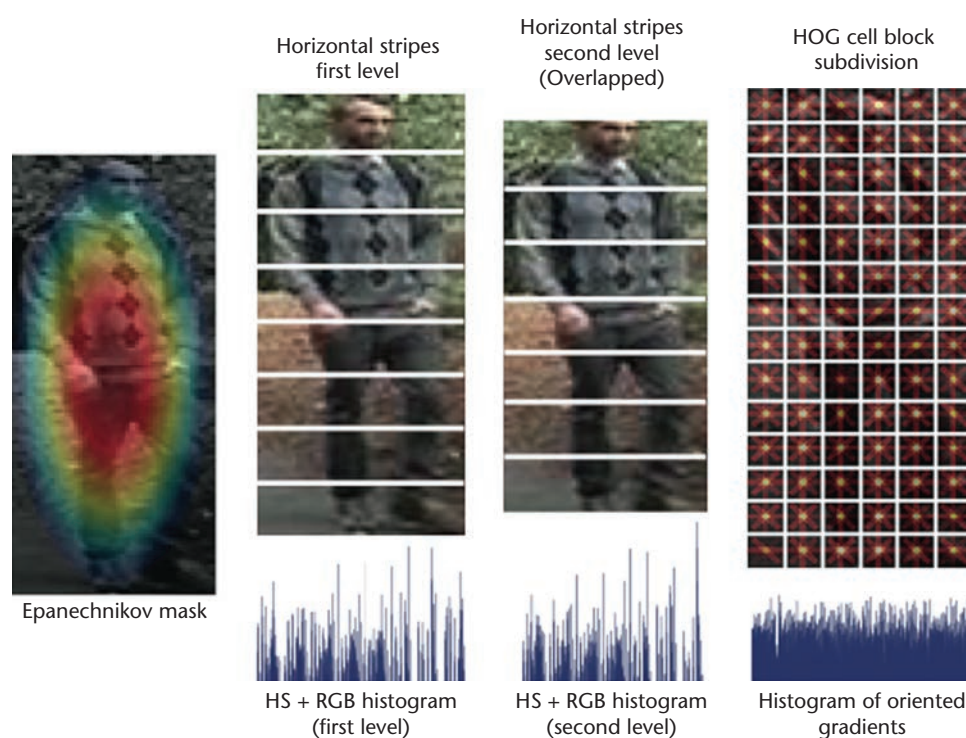
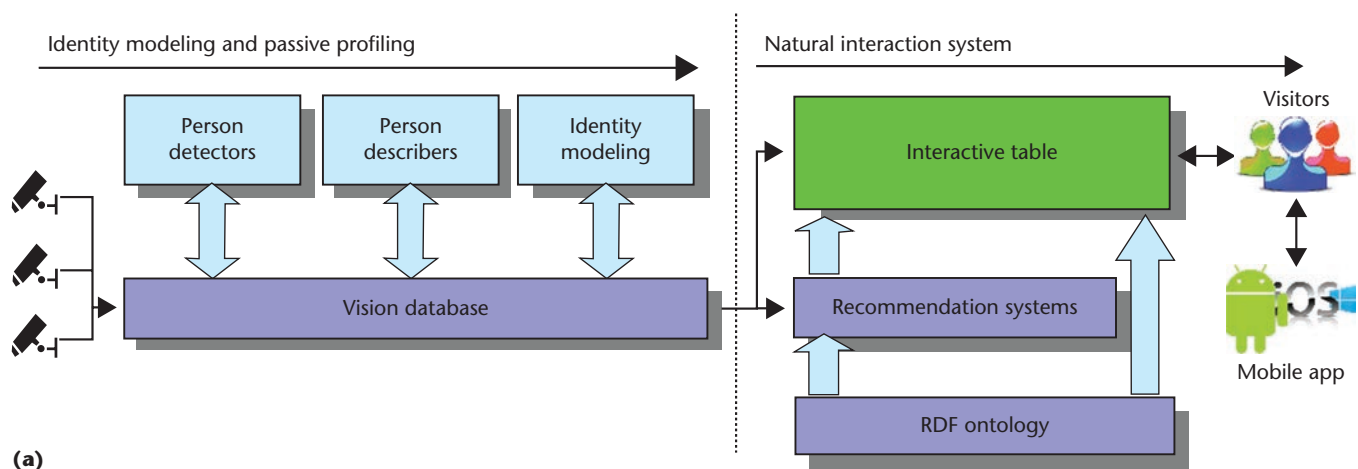


Figure 3. The Mnemosyne system. (a) System architecture and (b) person reidentification model with overlapping horizontal stripes to provide higher invariance to illumination variations.

Computer vision technology gives visitors the capability to learn more about the luxury cars in the exhibit in a sort of interactive game (see Figure 6). Visitors can use the glass camera to recognize their own gestures¹¹ and the computer vision app in their smartphone to recognize certain details on the physical cars. The algorithm effectively recognizes the three-dimensional details of the cars.

DICET and SMST

Two large-scale, three-year cultural heritage projects were launched in Italy in 2013 with the goal of improving the quality of visitor experience with enhanced interactivity and social connectivity, using computer vision for online profiling. The DICET project (a living lab for Culture and Technologies) will experiment with augmented visits to outdoor cultural heritage

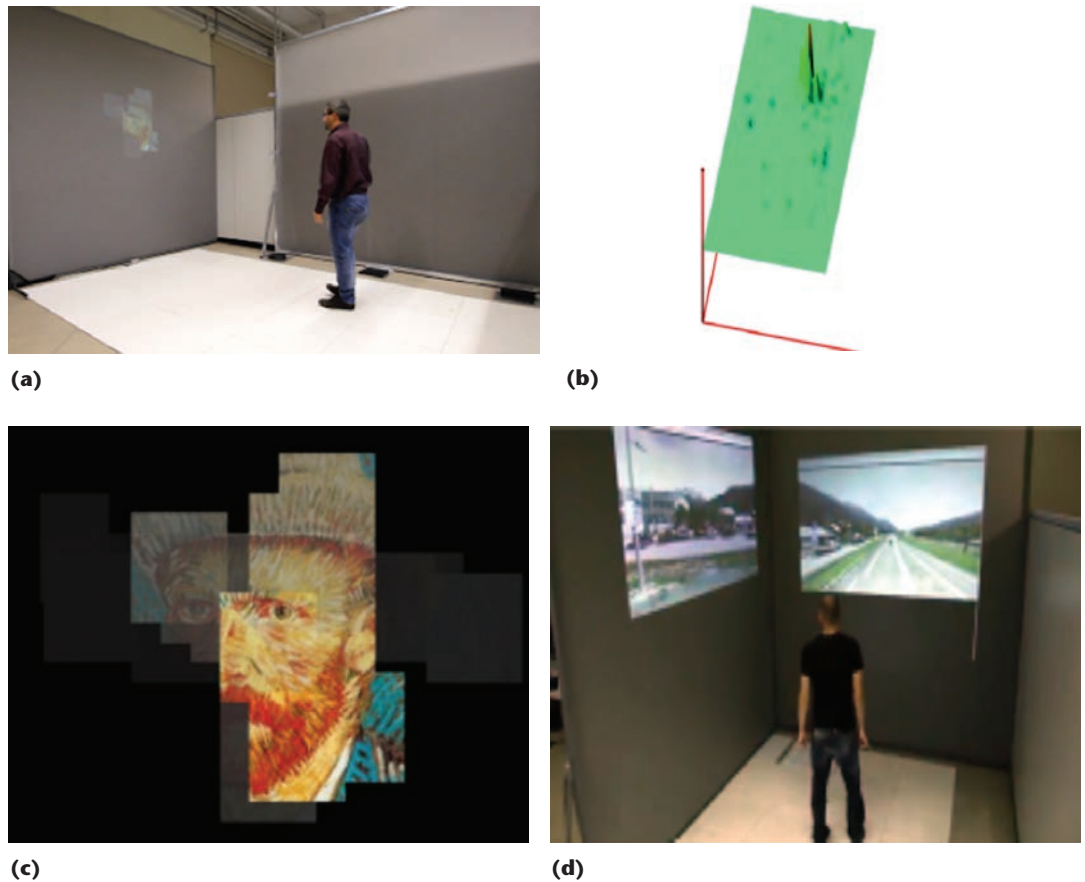


Figure 4. *The FlorimAge project. (a) Sensing floor using a single person experimental setting, (b) the pressure image, and (c) an example environment reaction to the person's walking trajectory or (d) behavior.*

sites in Southern Italy. An ego-vision system using wearable devices will implement gesture recognition so users can point to cultural heritage items and receive qualified information from the Web.

The Social Museum and Smart Tourism (SMST) project will provide specialized functions and services with experimental settings in Venice, Florence, and Rome. Envi-vision solutions will perform visitor reidentification and behavior analysis in both outdoor and indoor contexts. Ego-vision on smartphone devices will perform real-time object recognition. Both will help to provide personalized suggestions with context adaptation.

Questions to Answer

A primary goal of the computer vision capabilities described here for museums or art and cultural heritage exhibits is to augment the visitor experience in a natural and nonintrusive way. However, several technical questions must be

addressed before we can effectively deploy computer vision in such real settings:

- How can vision capabilities be implemented more effectively? Most current computer vision systems operate with fixed cameras. These are easy to calibrate but have poor resolution at far distances and require a networked configuration for large areas. More effective solutions could be implemented with robotic or mobile cameras, but these are much harder to calibrate and implement. Recognition of social activities, detection of social groups, and detection of group behaviors in crowded scenes and cluttered environments are of great interest but additional research is required to achieve satisfactory performance.
- To what extent can human vision capabilities be replicated? Humans can recognize objects with quick glimpses and only a few distinguishing details because of their



(a)

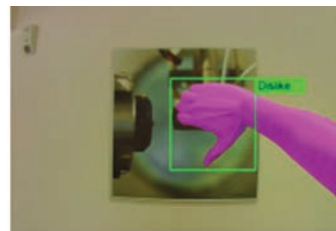


(b)

Figure 5. Onna Social House. (a) Interactive wall and (b) people interacting with the wall during the opening.



(a)



(b)

Figure 6. Tell_Me_Where ego-vision system. (a) The Enzo Ferrari Museum in Modena. (b) Tell_Me_Where recognizes visitor gestures and provides car details so visitors can learn more about the cars.

long-life learning capabilities. Similar capabilities are still unattainable by computer vision systems.

- How can detection of nontrivial art concepts be extracted from observations? Computer vision has proven successful in performing automatic object and event annotation for simple concepts. More complex concepts, however, such as those related to artwork and cultural assets are much more difficult to extract and express in a meaningful way.
- Should we reconsider vision systems for new images? With images and videos generated from sensors such as multispectral and

depth cameras or sensing surfaces, pixels are not samples of luminance and color and invariant representations do not apply. New techniques for pattern recognition and content understanding are therefore required.

Assuming that researchers will solve such technical problems given the progress of technology, many other questions on the social side remain open and require investigation.

Computer vision systems may be installed with good intentions, but privacy issues still exist. For example, imagine a person visiting a museum where a computer vision system has been installed to obtain the visitor's current

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profile. Target obfuscation may help anonymize a person's identity, but it is not always effective. Thus, if visitors don't want to be monitored, museums and institutions must have mechanisms that respect each visitor's personal privacy.

In another scenario, a visitor with a more positive disposition toward technological innovations might arrive wearing cameras that provide interesting information during the visit. It is important to determine how much information should be delivered to these visitors. Offering the visitor only a few trivial bits of data would be a missed opportunity to provide a valuable augmented experience. On the other hand, too much information could cause information overload, resulting in a cognitively tiring and affectively unsatisfactory visit.

If two or more people are visiting a museum together, they could become upset if they are interrupted or continuously disturbed by an "intelligent" system attempting to feed new information, even if that information is relevant to their current position. In this case, the computer vision system must provide the visitor with a degree of control to ensure it supplies the right information at the right time. Also, which modes of interaction are nondistractive?

Ultimately, the goal of a computer vision system is to provide appropriate information at the right time and place that fits both the cognitive and situational conditions to ideally augment a visitor's experience. Nevertheless, such systems should not end up alienating visitors from one another or not leave enough time for visitors to communicate with other people. Such asocial conditions may cool down the affective experience.

Conclusion

Computer vision is an extraordinary enabling technology for augmenting visitor experiences. Future research must address these technological and implementation challenges to best serve visitors and users.

MM

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Svebor Karaman, Giuseppe Lisanti, and Daniele Pezzatini.

References

1. L. Roberts, "Affective Learning, Affective Experience: What Does It Have to Do With Museum Education?" *Visitor Studies: Theory, Research, and Practice*, vol. 4, A. Benefield, S. Bitgood, and H. Shettel, eds., Center for Social Design, 1992, pp. 162–168.
2. C. Rocchi et al., "The Museum Visit: Generating Seamless Personalized Presentations on Multiple Devices," *Proc. 9th Int'l Conf. Intelligent User Interfaces (IUI) ACM*, 2004, pp. 316–318.
3. A. Mody et al., "Enhancing User Experience at Museums Using Smart Phones with RFID," *Proc. IEEE Long Island Systems, Applications and Technology Conf. (LISAT)*, IEEE, 2009, pp. 1–9.
4. Y. Suh et al., "A Mobile Phone Guide: Spatial, Personal, and Social Experience for Cultural Heritage," *IEEE Trans. Consumer Electronics*, vol. 55, no. 4, 2009, pp. 2356–2364.
5. Y. Wang et al., "Cultivating Personalized Museum Tours Online and On-Site," *Interdisciplinary Science Rev.*, vol. 34, nos. 2–3, 2009, pp. 139–153.
6. S. Zeki, *A Vision of the Brain*, Wiley-Blackwell, 1993.
7. E. Kandel *The Age of Insight: The Quest to Understand the Unconscious in Art, Mind, and Brain, from Vienna 1900 to the Present*, Random House, 2012.
8. A. Bagdanov et al., "Mnemosyne: Enhancing the Museum Experience through Interactive Media and Visual Profiling," *Multimedia for Cultural Heritage*, vol. 247, Springer, 2011, pp. 39–50.
9. M. Lombardi et al., "Human Behavior Understanding with Wide Area Sensing Floors," *Human Behavior Understanding*, LNCS 8212, Springer, 2013, pp. 112–123.
10. A. Ferracani et al., "Indoor and Outdoor Profiling of Users in Multimedia Installations," *Proc. 20th ACM Int'l Conf. Multimedia*, ACM, 2012, pp. 1197–1200.
11. G. Serra et al., "Hand Segmentation for Gesture Recognition in Ego-Vision," *Proc. 3rd Int'l Workshop Interactive Multimedia on Mobile and Portable Devices (IMMPD)*, ACM, 2013, pp. 31–36.

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Machine-to-Machine Communication

Michael Weyrich, Jan-Philipp Schmidt, and Christof Ebert

Although wireless communication is integral to our daily lives, there are numerous crucial questions related to coverage, energy consumption, reliability, and security when it comes to industrial deployment. Michael Weyrich, Jan-Philipp Schmidt, and I provide an overview of wireless machine-to-machine (M2M) technologies. I look forward to hearing from both readers and prospective column authors about this column and the technologies you want to know more about. —*Christof Ebert*



IMAGINE A WIDESPREAD manufacturing plant equipped with smart machinery and RFID-enabled technology. All machines are interconnected and communicate through their sensors and actuators as they work their way through the manufacturing process. Operators use wireless pads and connect to production systems for diagnostics and manufacturing oversight. Machine load, status, and diagnosis data are further aggregated in enterprise systems for resource planning and production optimization. The machines receive usage feedback to adjust production schemes and therefore optimize cost and quality. The machines also communicate with their own manufacturers to request repairs or order new parts to avoid costly outages. Agent-based systems allocate load to machines in a distributed, often global, production setup to optimize supply-chain cost.

Future fantasy? No, this is a growing reality in what we call the smart factory. The smart factory of the future is far more agile than the approaches in today's

flexible manufacturing. The smart factory connects the machines, devices, logistics, and humans to perform the necessary coordination ubiquitously and ad hoc.

The same concepts that seamlessly connect various devices in the field with management and enterprise IT apply not only to automation and production industries. For instance, we've already introduced the machine-to-machine (M2M) approach in transport, such as for vehicle diagnosis or for connecting vehicles with information systems. The same is true for healthcare with implanted devices or aerospace for global parts tracking. For consistency, we'll stick with M2M communication in the smart factory in this article, but we invite you to apply it in your own industry.

Machine to Machine

The future smart factory and supply chains need ubiquitous communication among a plethora of production units, services, diagnoses, handheld devices, and enterprise systems in the push to

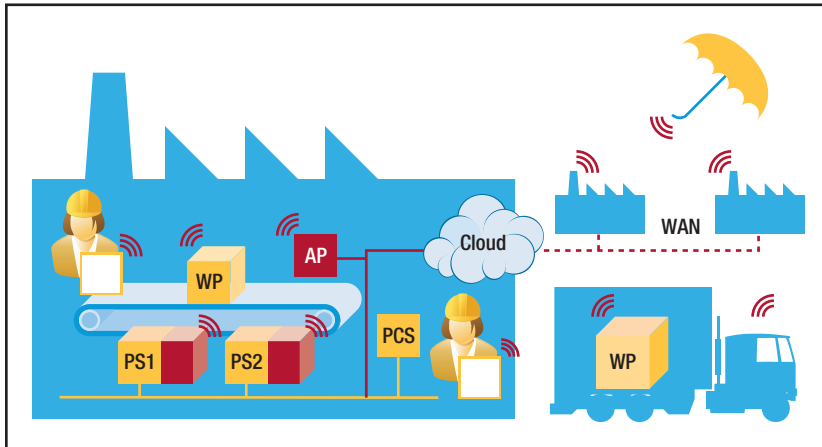


FIGURE 1. Communication in a smart factory. The work pieces and processing stations are equipped with advanced wireless communication to allow the tracking of material at any time. In this way, the materials navigate intelligently. (PS: processing station; WP: work piece; PCS: process control system; AP: access point; and WAN: wide area network.)

design, manufacture, and service goods. This is fairly obvious to most forward-looking engineers, but reality shows that the exploding number of often ad hoc connected sensors, controllers, and actuators is creating swarms of devices that are difficult to organize in an industrial network.

For a smart factory to prevail, communication technologies will need to efficiently connect machinery over varying distances in a flexible manner with high security, robustness, and availability at a low cost. One option is self-organizing logistics, but logistics becomes difficult once the number of product variants increases and production volumes fluctuate. The risk of supplier shortages or errors in the supply chain intensifies with complexity. M2M communication provides a solution by registering and tracking material, pallets, trucks, and so on.

M2M connects production and automation with enterprise IT. The Organization for Economic Cooperation and Development (OECD) esti-

mates that there were roughly 2 billion M2M devices globally in 2013. Communication suppliers such as Cisco and Ericsson estimate that by 2020, 100 billion devices will communicate M2M. Assuming low-cost communicating technology embedded in components, this number could skyrocket even higher. Forrester Research and others see the current global sales volume of M2M as close to US\$10 billion with an expected \$50 billion by 2020. Again, that's a rather conservative estimate that's amazing to see.

Wired technologies have matured over the years and are widely used in M2M communication. However, they're rather static in their setup, depending on a wiring scheme that's costly to change. They also feature demanding infrastructures and topologies that are well designed without knowing future demand. Cables play a key role in today's communication, but their continued use is questionable for future needs.

Wireless M2M communication is

slowly entering the production process. RFID and WLAN technologies are cost-effective and seamless to install and operate on a global basis, but clearly don't yet fully address the industry production needs of all possible applications. Engineers from domains such as automation, automotive, transport, and medical all face the same questions when engineering a new automation project: Which wireless technologies are available to fulfill what type of demands from which applications? What are the criteria for choosing among the different wireless technologies on the market today? Which technologies are easy and cost-effective to engineer, build, and operate?

As a case in point, smart factories can use new organizational approaches due to advanced communication technology. Consider Figure 1, in which each device relevant to manufacturing is equipped with individual communication facilities. In the future, each product and its components and parts will carry communication tags, and those elements of production and logistics will remain traceable and manageable even in the event of unforeseen circumstances, such as rerouting. Shortages and supply mistakes will be quickly rectified, and machine diagnostics easily performed and resolved. Without wireless M2M communication, such an evolution isn't feasible.

Wired or Wireless?

Networks can be both wired and wireless, but wireless M2M protocols are increasingly used because they're convenient to install, use, maintain, and enhance. Today, there's no single M2M interface serving as a global standard. Interfaces between machines depend on the industry segment—for instance, the automotive

industry has area controller networks (CANs) inside cars, and the energy industry has its M-Bus to remotely read meters. Standards definition is increasingly dominated by alliances of IT suppliers due to the high economic relevance of seamlessly connected devices. Google's acquisition of Nest Labs shows the relevance of connecting consumer products and classic IT.

Wired M2M technology is widely applied today due to its robustness and availability, which are demanded in critical environments where security or explosive hazards must be considered. When such constraints don't apply, wireless technology can reduce deployment cost, provide access to remote or difficult locations, and has the advantage of not involving cabling. The biggest advantage is ubiquity: with wireless M2M, the position and status of anything processed in the factory is known at every stage and can be seamlessly connected to ERP and other enterprise-level IT environments.

To ascertain a wireless technology's suitability, you need to know the characteristics of the different offerings. Today, the physical transport layer is based on ISM bands: 2.4 GHz, 5 GHz, and 868 MHz. Various standards are available, such as IEEE 802.11 for wireless LAN, IEEE 802.15.1 for WPAN/Bluetooth, or IEEE 802.15.4 for low-rate wireless private area networks (PANs). Unfortunately, there's still the very real problem of similar-frequency bands overlapping with each other, partially blocking frequencies or causing disturbances.

Obviously, M2M communication needs more than a discussion about standards for the physical and data link layers. New protocol stacks support wireless network technologies

and protocols for communication with low bandwidth or limited memory consumption (<http://postscapes.com/internet-of-things-protocols>). The Internet of Things also has strong requirements for the address space in devices and the way messages are communicated.

vides real-time, dependable, high-performance communication between machines.

The Path Forward

Moving beyond mere protocols, we can find several industry-ready wireless technologies that vary in

Seamless M2M communication will boost innovation such as smart factories and networked cars.

IPv6 has facilitated M2M communication by resolving the address space problem but with only a small percent of data used for the M2M application and the rest dedicated to message overheads, IPv6 isn't efficient for energy-constrained applications.

To counteract this, several energy-efficient wireless M2M protocols are available. Message Queue Telemetry Transport (MQTT; www.mqtt.org) is a simple and lightweight messaging protocol designed for constrained devices and low-bandwidth, high-latency networks with low reliability needs. Invented in 1999, it is currently undergoing standardization at the Organization for the Advancement of Structured Information Standards (OASIS). The Constrained Application Protocol (CoAP), another energy-efficient protocol used to communicate interactively over the Internet, translates HTTP for sensors and switches, thereby facilitating machine connectivity to the Internet of Things with low overheads. The Data Distribution Service (DDS) protocol is a specific M2M middleware that pro-

coverage, data rate, and usage. Wireless product solutions are usually based on IEEE standards but are increasingly defining additional specifications and providing product qualification programs, certification, and promotion.

Table 1 gives an overview of today's most relevant wireless technologies. It highlights nine current technologies for wireless M2M, along with a typical use case (including commercial availability of devices), encoding features for providing secure communication (range, throughput, and infrastructure), efficiency, chip size, integration effort to add devices into networks, cost, and scaling potential.

Key decision drivers for the choice of products include investments for hardware, costs, and speed to adjust and extend a network and integrate new devices. However, additional requirements also affect the final choice: energy efficiency, chip size, and security.

For instance, if a wide area wireless connection is required to interconnect vehicles for diagnosis,

Table 1. Overview of wireless technologies.

	Use cases	Sector	Range	Through-put	Infrastructure needs	Efficiency	Chip size
LTE	Wireless communication for mobiles and data terminals	IT and communication	10 km	150 Mbit/s	Complex infrastructure from provider	High	Small
WLAN	Wider Internet access	Multiple sectors	100 m	600 Mbit/s	Router, access points	High	Medium
Bluetooth	Product interface	Consumer	100 m	706.25 kbits/s	No special infrastructure, point to point (p2p)	Low	Small
ZigBee	Device control	Consumer and industrial equipment	100 m	250 kbit/s	Access points	Low	Large
Wireless HART	Sensors and actuators	Process, industry	250 m	2 measurement	HART gateway to the fieldbus	High	Large
Industrial WLAN	Sensors and actuators	Process, industry	100 m	450 Mbits/s	Access points, gateways to the fieldbus	High	Large
EnOcean	Energy harvesting, smart homes	Building, automation	30 m	125 kB/s	Transceiver modules	Very low	Large
RFID	Non-contact identification and tracing	Many industries	6 m	100 kbit/s	Tags, scanner	Very low	Very small
NFC	Radio communication	Smartphones	10 cm	424 kbits/s	Smartphones, tags	Very low	Very small
	Integration effort	Cost	Scaling potential	Encoding	Market Readiness	URL	
LTE	High	Low	Low	AES128	Mature for wide usage	www.3gpp.org/technologies/keywords-acronyms/98-lte	
WLAN	Very high	Low	High	WPA2	Mature for wide usage	www.radio-electronics.com/info/wireless/wi-fi/ieee-802-11n.php	
Bluetooth	Low	Low	High	AES128	Mature for wide usage	www.bluetooth.com/Pages/what-is-bluetooth-technology.aspx	
ZigBee	High	High	High	AES128	Mature for wide usage	www.zigbee.org/About/AboutTechnology/Standards.aspx	
Wireless HART	Low	High	Low	AES128	Niche markets	www.hartcomm.org/protocol/training/training_resources_wihart.html	
Industrial WLAN	Very high	High	High	WPA2	Niche markets	https://a248.e.akamai.net/cache.automation.siemens.com/dnl/TM/TM0MTMzAAAA_90880063_HB/22681042_Aufbau_IWLAN_DOKU_V30_en.pdf	
EnOcean	High	Low	Medium	ARC4 or AES	Certain sectors	www.enocean.com/fileadmin/redaktion/pdf/articles/perpetuum_radio_standards_en.pdf	
RFID	Low	Low	Low	Not required	Mature for wide usage	www.rfid-journal.de/rfid-technik.html	
NFC	Low	Low	Low	Not required	Upcoming	www.nfc24.info	



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vehicle ad hoc network, and fleet management, LTE is the technology of choice. It offers reasonable coverage in many regions.

However, WLAN and ZigBee would be the choice for service technicians in industry using mobile access devices. Both networks provide a high data rate, don't need centralized communication infrastructures and overhead, are secure, and can be provided with reasonable coverage in manufacturing sites. NanoLOC, a technology for tracking objects based on the ZigBee standard, is suitable to detect work pieces in widespread industrial production sites.

Some other use cases require low-range object identification or near-field communication (NFC). RFID is an established technology for identifying objects such as work pieces; NFC can help exchange data between objects in close proximity.

Many special interest groups have emerged around wireless M2M technology and the attempts to use it to evolve and promote product solutions. Bluetooth has an interest group of more than 20,000 companies, and the ZigBee Alliance hosts a thriving global ecosystem of businesses, universities, and government agencies to grow that particular standard and a solution space with products around it.

The HART Communication Foundation and products such as Industrial-WLAN are more focused on the industrial automation application fields. Once a wired HART or Profinet infrastructure is available, Wireless-HART or Industrial-WLAN make sense in terms of compatibility: existing industrial wired infrastructures can be connected easily, especially remote sensors or diagnostics that are difficult to access. The EnOcean Alliance pro-

vides applications with low power and energy harvesting needs, and EnOcean-enabled switches can be powered by batteries or harvested energy because the transmitters have very low power consumption.

A critical success factor of M2M protocols is their energy-efficiency. Batteries are certainly not a first choice as they need service and are ecologically damaging. For example, Bluetooth and ZigBee provide several energy-safe modes when no communication between master and slave is necessary. Moreover, RFID tags can be activated with transducers, before data can be written and read, thus boosting energy efficiency.

With the rapid progress toward applications with ad-hoc connected devices, seamless M2M communication will boost innovation such as smart factories and networked cars. Our entire engineering environment will change based on these new ways to interconnect devices, machines, and products, starting with production and covering the entire product life cycle. Smart factories and big data have ignited some sparks, but the fire of seamless ubiquitous communication will grow faster and bigger than what we can imagine with today's manually installed communication systems. 

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Alan Turing

George Strawn, NITRD

Editor's Introduction

Welcome to *IT Professional's* new Mastermind department, which will profile innovators, inventors, and key people in the fields of IT, computer science, and information systems. Many of us have our IT heroes, and I encourage you to let me know who you would like to see profiled. You can also submit your own short article on your person of choice. Please contact me at gostrawn@gmail.com for more information.

— George Strawn

As the editor of this new department, I have the privilege of choosing the first person to profile. Reflecting on who to select, Alan Turing, the father of computer science, seemed a good choice, given that his contributions were both practical (World War II code breaking) and theoretical (the Turing machine).

Much has been written about Turing,¹⁻⁶ so my remarks will be highly selective and at times opinionated, and I welcome your feedback. (Indeed, I hope to run a "Reader Response" sidebar in the next issue, highlighting any feedback I receive.) I decided to focus on Turing's early theoretical work, because it's unusual for a major theoretical result to precede any practice in a field (see

the related sidebar for more on Turing's contributions). Consider how different the computer's history is from that of the steam engine. The science that explained how the steam engine worked—thermodynamics—was developed long after it had been in use. This order of events gave rise to the saying, "thermodynamics owes more to the steam engine than the steam engine owes to thermodynamics." However, in this case, it could be said that the computer owes more to computability theory than computability theory owes to the computer.

A Prehistory of Computers

Computers were preceded by mechanical and electromechanical calculators. Mechanical calculators have a long history, including

contributions by Blaise Pascal, Gottfried Wilhelm Leibniz, Charles Babbage, and Ada Lovelace. Electromechanical calculators were developed around the beginning of the 20th century. Herman Hollerith, for example, created punch-card data-processing machines that became the backbone of IBM for its first 50 years. The triode vacuum tube was also developed early in the 20th century, and it greatly improved both telephone and radio reception.

However, when Turing began his work on "theoretical computing machines," vacuum tubes had yet to be applied to calculation. (Next issue, I plan to highlight three individuals—John Vincent Atanasoff, John Mauchly, and John von Neumann—whose cumulative work resulted in the use of vacuum tubes to implement Turing's "universal" machine.) With no immediate thought about practical computing, Turing set about to give a formal definition of what it means to be computable.

The Decision Problem

In the mid-1930s, the young Alan Turing was a budding theoretical

mathematician. One problem he decided to tackle, called the “decision problem,” asked if a procedure could be created that would answer yes or no as to whether a given logical statement was decidable from a given set of axioms. He envisioned such a procedure as a mechanical process that would follow explicit instructions and not require any intelligence.

Turing devised a simple process for creating theoretical machines that could implement such procedures, and he conjectured that these machines could compute anything that was computable (in other words, they defined computability).

The Turing Machine

Since a Turing machine implements a procedure that consists of a sequence of instructions, there must be a *memory* that holds intermediate results. The memory component of a Turing machine is a data tape and read-write head, where symbols could be read from and written onto the tape. The tape could move in either direction, so any part could be brought under the read-write head. Moreover, if either end of the tape were about to move beyond the read-write head, more tape would be spliced on, so that the read-write head always had tape on both sides of it.

The computational component of the Turing machine was a finite set of instructions, each of which was of the following form: if the symbol x is under the read-write head, and the current “state” (each Turing machine has a finite set of states, usually represented as positive integers) of the machine is n , then change the state to m and write the symbol y over the x on the tape and/or move the tape one square to the left or right. The input to the computation was initially placed on the tape, and the output was found on the tape if the execution terminated.

Turing’s Contributions

Here’s a list of some of Alan Turing’s major contributions:¹

- *computability*: the universal Turing machine and Turing reducibility;
- *crypto-analytics*: breaking the enigma code during WWII;
- *computation*: developing the electromechanical “bomb” to speed up enigma deciphering;
- *artificial intelligence*: the Turing test; and
- *mathematical biology*: morphogenesis and the Turing hypothesis of pattern formation.

Reference

1. *Alan Turing: His Work and Impact*, S. Barry Cooper and J. van Leeuwen, eds., Elsevier Science, 2013.

The Unsolvability of the Halting Problem

Turing first proved that there could be no general procedure for verifying that such a machine would complete its execution, rather than getting stuck in an infinite loop. (This result, called the “unsolvability of the halting problem,” has been observed by hapless programmers ever since.) The essence of Turing’s proof was that any such algorithm could be made to contradict itself, and, therefore, it could not exist.

From the unsolvability of the halting problem, Turing deduced that the decision problem was also unsolvable. But his third result was even more portentous. He proved that a universal Turing machine exists—a Turing machine that could simulate any other Turing machine. In other words, its tape could be initialized with input for a given Turing machine and its instructions. Then, it could simulate the execution of those instructions applied to the input on the tape. Thus, the universal Turing machine is a theoretical analog to today’s computer hardware, and the instructions of a simulated Turing machine is a theoretical analog to a computer program. All this was done a decade before the first stored program computer was built.

Defining Computability

At about the same time Turing was defining his machine, a small number of other investigators were discovering different ways to define computability. Although the various ways differ widely, they have all been shown to be equivalent, and the so-called Church-Turing thesis asserts that these equivalent processes do capture what it means to be computable. (Church defined one of the equivalent schemes, called the *lambda calculus*, which became the basis for the programming language Lisp.)

How does computability apply to the mathematics of real numbers? It might surprise you to learn that most mathematicians believe that “almost all” real numbers are not computable. Computable real numbers are those for which there is an algorithm (a Turing machine) that can crank out as many digits of their infinite sequence of digits as desired. Examples of computable numbers are the square root of 2, e , and π . Since at least the beginning of the 20th century, a small number of mathematicians have taken a more computable approach to mathematics, reducing the use of uncomputable numbers and sets. The reason I mention the issue of

mathematical computability is to suggest that someday the increasing influence of the computer could actually change how mathematics is defined.

The computer has already changed the way science is defined. We now talk about four modes of science, adding computational science and data-driven science to theory and experiment. These new modes and their masterminds will be highlighted in future articles.

Sadly, this view into Turing's work concludes with a barrier Turing couldn't overcome in his brief lifetime. In the 1950s, homosexuality was illegal in England, and Turing, who was admittedly gay, was arrested and convicted. As an alternative to prison, Turing was subjected to "chemical castration," and after his "treatment," he apparently committed suicide, although conspiracy theorists have suggested he might have

been killed as a "security risk," given all he knew about WWII code breaking activities. Regardless of the direct cause of his untimely death at the age of 42, what was said about Antoine Lavoisier's execution in France during the French Revolution could be said about Turing's death: it took England a thousand years to create such a man, and only a short time to destroy him. In September 2009, British Prime Minister Gordon Brown made an official public apology on behalf of the British government for "the appalling way [Turing] was treated." And on Christmas Eve 2013, Alan Turing was given a posthumous pardon by Queen Elizabeth.⁷

References

1. *Alan Turing: His Work and Impact*, S. Barry Cooper and J. van Leeuwen, eds., Elsevier Science, 2013.
2. B.J. Copeland, *Turing: Pioneer of the Information Age*, Oxford University Press, 2013.
3. H. Henderson, *Alan Turing: Computing Genius and Wartime Code Breaker*, Facts on File, 2009.
4. A. Hodges, *Alan Turing: The Enigma*, Walker & Company, 1983.
5. D. Leavitt, *The Man Who Knew Too Much: Alan Turing and the Invention of the Computer*, W.W. Norton & Company, 2006.
6. S. Turing, *Alan M. Turing*, W. Heffer & Sons, 1959.
7. C. Davies, "Enigma Codebreaker Alan Turing Receives Royal Pardon," *The Guardian*, 24 Dec. 2013; www.theguardian.com/science/2013/dec/24/enigma-codebreaker-alan-turing-royal-pardon.

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Should Sniffing Wi-Fi Be Illegal?

Paul Ohm | University of Colorado Law School

On 21 December 1996, Mr. and Mrs. Martin of Fort White, Florida, were driving to the mall to do some Christmas shopping while listening to Mr. Martin's police scanner. Suddenly, they heard recognizable, famous voices—those of powerful Republican members of Congress, including then Speaker of the House Newt Gingrich. These politicians were crafting a response to ethics charges against Gingrich, which were going to be announced later that day. The Martins could hear the conversation because one person on the call, an up-and-coming congressman named John Boehner, was using an analog cell phone from his parked car, which they happened to be passing. The Martins recorded the call on a cassette and shared it with Representative Jim McDermott, then the Democratic ranking member of the House Ethics Committee, who leaked a transcript to several news outlets.

Soon, the Martins and McDermott learned firsthand several lessons about the unyielding seriousness of US wiretap laws, which said that they had illegally invaded the privacy of the people on that call. The Martins learned that the law treads not lightly on wiretapping, declaring it a felony punishable by up to five years in prison. Rather than risk this sentence, the Martins pled guilty to misdemeanors and paid fines of US\$500 each. McDermott learned that the law prohibits not only the initial interception of private conversations but also the downstream use. Sued by Boehner,



McDermott fought back, asserting a First Amendment defense. The court ultimately ruled against McDermott, finding that the admittedly important First Amendment values at stake were trumped by the vital purposes of wiretap laws and the need to deter other would-be wiretappers. The court ordered McDermott to pay more than \$1 million dollars to cover Boehner's legal fees.

Flash forward several decades to another car, driving down another road, also surreptitiously scanning the airwaves, bearing even more sophisticated radio surveillance equipment. Google's famous Street View car intercepted and stored the headers and contents of data packets of anybody using Wi-Fi within range of its powerful antennas. (Although Google captured

incomplete packets, still, according to one investigation, it ended up capturing email account passwords and the content of email messages.¹) But what really separates Google's actions from the Martins' is scale. Google sniffed packets through not one but legions of Street View cars, over four years, in 30 countries. In total, the company collected 600 Gbytes of unencrypted, private information. We might never know for sure how many people had their private communications plucked out of the air by Google, but it seems plausible that they number in the millions.

Like the Martins and McDermott, Google has been embroiled in legal controversy ever since. US regulators have largely given Google a pass for its conduct, and as far as

we know, no criminal investigations were opened. But European regulators continue to press investigations into the alleged misconduct. In addition, a class-action lawsuit on behalf of those whose packets were intercepted, alleging a violation of the federal Wiretap Act, has thus far survived Google's motion to dismiss. Most recently, in September 2013, a federal appeals court rejected Google's motion, allowing the company's headaches to continue, if not compound.

I'll leave it for other times and people to untangle the difficult legal questions at this case's heart. (See, for example, Bruce Boyden's great series of blog posts.²) I ask instead, what should the law say about this? This fascinating question not only has ramifications for Wi-Fi and wiretapping but also poses broader questions about how we use law to protect online privacy. It leads us to consider many important and recurring debates on the collision of law and technology.

Maybe Sniffing Should Be Legal

Some people have argued that it should be legal to intercept communications transmitted over Wi-Fi. Their arguments take several forms. First, it shouldn't be illegal to do what's so easy to do. Criminalizing what's only "natural" seems to offend some deep sense of fairness. Second, and related, if people are so worried that others will learn what they transmit using Wi-Fi, they should encrypt their communications.

Third, even if wiretap laws protect privacy values, this benefit is outweighed by the benefits of unfettered access to the airwaves. Google claims that its Street View cars sniffed Wi-Fi packets to improve its map products. By compiling a database of the addresses of the world's Wi-Fi access points, Google can pinpoint your location on the globe (for your, or maybe advertisers', benefit)

by recognizing the signatures of the access points in your proximity.

Finally, the potential criminalization of Wi-Fi sniffing seems to threaten crucial values of openness, experimentation, and curiosity. When Wi-Fi was still young, people memorably took to the streets toting Pringles cans³ and modified laptops, searching, mapping, and sharing databases full of information obtained over open Wi-Fi networks. These *wardrivers* represented a link in a long chain of curious innovators, the kind of people who built the Internet. It would be an affront to declare what they do illegal.

On the Other Hand

As it happens, Congress has faced arguments like these before, and it's instructive to examine how it responded previously. In 1986, when Congress was contemplating extending wiretap laws to cover computer networks, some people argued that it shouldn't be illegal to intercept conversations conducted over cordless phones. These simple, analog devices broadcasted and received over only a few unencrypted channels, and they had the troublesome tendency to accidentally pick up nearby conversations.

Initially, Congress accepted these arguments, carving an exception to the law for cordless phones. Although this exception seemed to cover cordless phones but not cell phones, still, under it, the Martins and McDermott would have had one more argument for why their conduct hadn't been illegal.

But in the first few years of the law, Congress learned that the trouble this distinction caused outweighed the possible benefits. In 1992, it amended the law again, bringing cordless phones (and similar items such as baby monitors) into its prohibition. It helped that in the intervening years, technologists had introduced innovations such as channel hopping

and scrambling to make accidental interception less likely.

Congress has acted once to tamp down arguments about the exceptional nature of radio communication; it should consider doing it again for Wi-Fi. This is because the arguments for the legality of sniffing might initially seem appealing but, on closer scrutiny, shouldn't carry the day.

The argument that things that are natural or easy to do shouldn't be illegal smacks of an unhelpful technological determinism. It treats technological developments as if they were products of nature, bestowed on us by some benevolent and mysterious force, one we should try not to subvert. This argument is misguided. Wi-Fi is simply a human product, one we should be able to control to avoid harm.

Also, what might be easy for experienced techies might not be easy for the average computer user, and our laws regulate the latter as much as the former (and there are many more of the latter, too). Even an average techie can find the software that modifies his or her operating system's networking stack to switch the interface into RFMON (Radio Frequency Monitor) mode, enabling his or her computer to capture packets. But how easily can the average network user do this? The vast majority of Wi-Fi users have never intercepted another user's packets and never will. Such behavior is rare and exceptional, even if it's easy for some. It seems much harder to believe that anybody can accidentally intercept Wi-Fi (much less the content of communications transmitted over it) in 2013 than it did to believe that people such as the Martins might accidentally intercept a cell phone call in 1996.

The argument that Wi-Fi sniffing's benefits can outweigh the harms to privacy is a red herring, at least in this case. Most wiretap laws apply only to collecting the contents

of communications, not merely to capturing addressing information transmitted in packet headers or Wi-Fi frames. If Google had restricted its collection to noncontent data such as SSIDs (service set identifiers) and MAC (media access control) addresses, as many Pringles-toting wardrivers have, it wouldn't have violated the Wiretap Act. (A separate law, the federal Pen Register and Trap and Trace Act, makes it a crime to use a device that collects "dialing, routing, addressing, and signaling information,"⁴ but this law is far less punitive than the Wiretap Act. It's also almost never enforced.) Google has never sufficiently explained why it needed to capture packet content to aid its mapping efforts.

Although the benefits of sniffing packets and wardriving might be important, I believe they're outweighed by the privacy values on the other side of the balance sheet. At the very least, privacy is important because it protects us from harm. Any Google engineer with access to the 600-Gbyte database of sniffed packets might be able to read the email messages you sent and received and the webpages you visited, as well as pinpoint your location at that moment in time. If you ever had the misfortune to be using a computer in a cafe, office, or home along a Street View car's path, Google engineers can know all of this. Maybe you wouldn't consider this harmful because you have nothing to hide; your life is an open book. But it seems likely that at least some of the millions who were spied on would object vehemently to having that information known, even if only to Google's engineers.

The US Federal Bureau of Investigation (FBI) and the US National Security Agency (NSA) can also access Google's information—for example, to track the history of a

fugitive or suspected terrorist (or, more troublingly, a political dissident or member of a religious minority). We don't know whether these agencies have accessed these data. However, given the recent revelations of NSA surveillance activities, it has become harder to argue that they lack the legal tools, desire, or sheerchutzpah to do such a thing.

Privacy has broader impacts too. Many have written about how we moderate our behavior when we think we're under a constant threat of surveillance. People tend to alter

**People tend to alter their thoughts
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unorthodox, slowly sanding away the
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their thoughts and actions, avoiding the edgy or unorthodox, slowly sanding away the sharp corners of personality—and society. Citizens have difficulty expressing, reading, or shaping political opinions, destroying the prerequisites for a deliberative democracy. Pervasive surveillance can disempower, allowing the watchers to subtly control the watched.

**Protecting the Foundation
of Privacy Law**

To protect privacy's vital values, I propose a new way of thinking about privacy law: we have two types of privacy law, each doing very different types of work. On the one hand, we regulate the finer points of particular kinds of dataflows and data stores through laws tailored to particular industrial sectors. These laws include the Health Insurance Portability and Accountability Act (HIPAA) for health information, Family Educational Rights and Privacy Act (FERPA) for educational records, and Gramm-Leach-Bliley (GLB) Act for financial records. They're subtle and nuanced; you

need a lawyer to understand them. In their ideal form, they strike a perfect balance, reflecting a carefully tailored risk assessment. We hope that a HIPAA-compliant hospital, FERPA-compliant school, or GLB-compliant bank will—merely by complying with the law—strike a reasonably good balance between mining the utility and safeguarding the privacy of data. But laws never achieve their ideal forms, meaning we doubt that today our laws strike this balance well. So, we tinker and hone, carving out exceptions here and bolstering protections there, to keep up with changing technological and societal conditions.

We need to build this layer of laws atop a firmer substrate made of bolder, broader laws. This second type of privacy law should help us construct meaningful boundaries between individuals and groups, and even between a single person's various personas, at least when these boundaries are desired. The lines these laws draw must be clear and easy for laypeople to understand. They needn't provide perfect privacy to all, but they should make very good privacy available to the motivated. These laws should never be riddled with exceptions and racked with subtlety. You should be able to understand them even if you haven't been to law school.

To me, the Wiretap Act has always been this second type of law. It was forged in the crucible of J. Edgar Hoover's aggressive surveillance tactics. Shortly after it was enacted, we were reminded of the need for it because of the Nixon administration's domestic surveillance that ultimately led to the Church Committee. Recent revelations about the NSA's seemingly boundless surveillance of the Internet drives home the need once again. The Act protects certain communication channels—telephones and

computer networks—from electronic surveillance, subject to a few narrow exceptions. It implements a fairly straightforward, unambiguous regime: don't intercept the content of communications without consent. If you do, don't disclose or use the information in any way, lest you commit a second crime. It's good that the courts have interpreted the Act broadly, overriding even objections raising important First Amendment values, as a reflection of the Act's important role.

But if we believe that the Wiretap Act plays a special, foundational role in protecting privacy, liberty, autonomy, and maybe even a flourishing, deliberative democracy, we must vigilantly protect it. We must reject calls to let it die a death of a thousand cuts. We should urge the opposite: Congress and the courts should reaffirm and strengthen its protections, and companies should avoid business models and legal arguments that eviscerate its safeguards.

This is why efforts to declare Wi-Fi sniffing legal under the

Wiretap Act are so worrisome. According to the arguments made in Google's motion to dismiss, the law that declared the Martins potential felons and cost Representative McDermott \$1 million dollars wouldn't apply to massive, invasive programs of data collection, simply because those data are sent using Wi-Fi. Under this interpretation, this bedrock privacy law would treat wired and wireless communication unequally and would drive a wedge between telephonic and computerized communication. Our bedrock of privacy protection would crumble with every technological advance. This isn't a tiny crack in the foundation of privacy law, it's a chasm that might undermine privacy law's entire structure.

Google needs to understand the ramifications of the arguments it has been making in litigation. It needs to consider that if its arguments prevailed—and, mercifully, they haven't yet—any interception of Wi-Fi would no longer be prohibited, whether done by

well-meaning companies, nefarious identity thieves, or the government. Google has argued that its interceptions were innocent and unknown, at least to managers. But its arguments would empower others with far more pernicious goals to conduct massive surveillance with impunity. I bet that FBI lawyers are silently cheering Google on from the sidelines. If Google's arguments ever carry the day, the FBI could sit outside cafes hovering up the communications of everybody inside, with no suspicion, without violating the statute. (To be sure, it still might be violating its own internal rules or the US Constitution.)

Congress could easily save us from this possibility. As it did back in 1992 when cordless phone calls' privacy wasn't assured, Congress should amend the Wiretap Act to unambiguously reaffirm that intercepting the contents of communications sent over Wi-Fi is a crime. So much is at stake. ■

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References

1. P. Sayer, "Google's Street View Wi-Fi Data Included Passwords, Email," *Infoworld*, 18 June 2010; www.infoworld.com/d/networking/google-street-view-wi-fi-data-included-passwords-email-679.
2. B. Boyden, "Why Google's Wi-Spy Argument Is Stronger Than It First Appears," blog, 19 Aug. 2013; <http://madisonian.net/2013/08/19/why-google-wi-spy-argument-is-stronger-than-it-first-appears>.
3. R. Block, "Wi-Fi Cantennas Now 'Illegal,'" 25 July 2005; www.engadget.com/2005/07/25/wifi-cantennas-now-illegal.
4. US Code, Title 18, sections 3121 and following.

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Training for the Gaming Industry

The University of Washington Bothell's Digital Future Lab may be unique on a college campus.

An interactive media R&D studio that focuses on developing original content to support education, entertainment, and social justice, the lab emphasizes students' role as creators and learners. There, students from all majors and concentrations have an opportunity to participate in project design and development.

Building video games is a particularly popular lab project. From the start, student team members—as developers, managers, and artist/designers—are involved in a full studio

production environment, gaining invaluable hands-on experience and insight into the development process not available in most classrooms.

Ongoing game refinements challenge student developers to improve programming and analytical skills, and learn relatively advanced concepts in areas such as AI and graphics. Developers also master basic game components and participate in the full scope of game creation, from initially programming the logic to implementing design modifications and choosing from diverse media assets.

Student project managers, level designers, graphic artists, and audio producers work

directly with developers on production code and must adhere to the same resource, time, and quality constraints that studio professionals face. They learn to tailor their creative ideas to match the parameters their peer developers can actually deliver. And the high standard the lab sets for final production quality requires students to achieve polished professional competencies comparable to those generally learned only through off-campus internships or as first-year career professionals.

Students also gain important team-building skills: communicating with members across disciplines, responding appropriately to different kinds of feedback and input, accepting and fulfilling their responsibilities as part of a group. Developers, project managers, designers, and artists inevitably visualize challenges and solutions in unique ways, and each

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Audio Director - Large Screen Devices or Other: Lead cross functional teams and driving system-level and sub-system designs through fast-paced product development cycles. <http://www.jobs-microsoft.com/job/go/240605500/>

Compliance Engineer-Devices Architecture and Silicon or Other: Delivers EMC & RF Compliant products to markets such as US, Canada, EU, etc. <http://www.jobs-microsoft.com/job/go/240410100/>

DfX Engineer – MSC – PEOPLE or Other: Manage the integration of DfX activities into the hardware product development schedule. This position requires domestic and international travel up to 25%. Telecommuting is permitted. <http://www.jobs-microsoft.com/job/go/240401500/>

Security Analyst-CnE BG or Other: Design, develop, and conduct global security investigations and tests on attacks targeting Microsoft's networks, operating systems, systems software, and digital assets. <http://www.jobs-microsoft.com/job/go/240397700/>

Senior Consultant: Deliver design, planning, and implementation services that provide IT solutions to customers and partners. Requires travel up to 75% with work to be performed at various unknown worksites throughout the U.S. Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/239731800/>

Senior Mechanical Engineer - Surface and PC Devices or Other: Lead development of new materials as well as fabrication and finishing processes. Requires international and domestic travel up to 25%. <http://www.jobs-microsoft.com/job/go/240348500/>

Senior Partner Technical Consultant-Global Business Support or Other: Deliver design, planning, and implementation services that provide IT solutions to customers and partners. <http://www.jobs-microsoft.com/job/go/240376700/>

Premier Field Engineer: Provide technical support to enterprise customers, partners, internal staff or others on mission critical issues experienced with Microsoft technologies. Requires travel up to 70% with work to be performed at various unknown worksites throughout the U.S.

Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/240582400/>

Premier Field Engineer - Global Business Support or Other: Provide technical support to enterprise customers, partners, internal staff or others on mission critical issues experienced with Microsoft technologies. Requires travel up to 40% with work to be performed at various unknown worksites throughout the U.S. Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/237792500/>

Technical Account Manager: Assure productive use of Microsoft technologies, focusing on delivery quality through planning and governance. Roving Employee—requires travel up to 100% with work to be performed at various unknown worksites throughout the U.S. Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/240631600/>

Premier Field Engineer - Global Business Support or Other: Provide technical support to enterprise customers, partners, internal staff or others on mission critical issues experienced with Microsoft technologies. Requires travel up to 75% with work to be performed at various unknown worksites throughout the U.S. Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/237796900/>

Technical Account Manager: Assure productive use of Microsoft technologies, focusing on delivery quality through planning and governance. Roving Employee—requires travel up to 100% with work to be performed at various unknown worksites throughout the U.S. Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/240356600/>

Hardware Engineer - Surface and PC Devices or Other: Design, implement and test computer hardware products that add strategic value to the company. <http://www.jobs-microsoft.com/job/go/240412900/>

WILSONVILLE, OR

Senior Automation and Controls Engineer - Large Screen Devices or Other: Design and manufacture leading-edge, large-format multi-touch display products used in sophisticated corporate and government environments. <http://www.jobs-microsoft.com/job/go/240360300/>

Electrical Engineer - LSD or Other: Participate in the design of all electrical aspects of a capacitive touch sensor and stylus. <http://www.jobs-microsoft.com/job/go/240300900/>

EDINA, MN

Account Technology Strategist: Formulate and execute an overarching technical and business strategy. <http://www.jobs-microsoft.com/job/go/239960700/>

Technical Account Manager: Assure productive use of Microsoft technologies, focusing on delivery quality through planning and governance. Requires travel throughout the U.S. up

to 25%. <http://www.jobs-microsoft.com/job/go/240348400/>

CHICAGO, IL

Premier Field Engineer-Global Business Support or Other: Provide technical support to enterprise customers, partners, internal staff or others on mission critical issues experienced with Microsoft technologies. Requires travel up to 50% with work to be performed at various unknown worksites throughout the U.S. Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/240324700/>

HOUSTON, TX

Application Development Manager: Provide customer access to wide range of product & application development expertise. Requires travel throughout the U.S. up to 25%. Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/240344700/>

Premier Field Engineer: Provide technical support to enterprise customers, partners, internal staff or others on mission critical issues experienced with Microsoft technologies. Requires travel up to 25% with work to be performed at various unknown worksites throughout the U.S. Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/239962700/>

BENTONVILLE, AR

Premier Field Engineers: Provide technical support to enterprise customers, partners, internal staff or others on mission critical issues experienced with Microsoft technologies. Roving Employee—requires travel up to 100% with work to be performed at various unknown worksites throughout the U.S. Telecommuting permitted. <http://bit.ly/MSJobs-Support>

MOUNTAIN VIEW, CA

Hardware Dev. or Design Engineers, Hardware Engineers, and Design Engineers: Design, implement and test computer hardware. <http://bit.ly/MSJobs-Hardware>

SAN FRANCISCO, CA

Design Verification/Validation Engineers: Responsible for ensuring the quality of Microsoft hardware products. <http://bit.ly/MSJobs-Hardware>

Premier Field Engineers: Provide technical support to enterprise customers, partners, internal staff or others on mission critical issues experienced with Microsoft technologies. Roving Employee—requires travel up to 100% with work to be performed at various unknown worksites throughout the U.S. Telecommuting permitted. <http://bit.ly/MSJobs-Support>

Service Engineers/Managers, Service Operations Engineers, and Systems/Operations Engineers: Plan, architect, deploy and/or support complex client/server or database software systems. <http://bit.ly/MSJobs-SysOps>

User Experience Researchers/Designers and User Research Engineers: Develop user interface and user interaction designs, prototypes and/or concepts for business productivity, en-

tertainment or other software or hardware applications. <http://bit.ly/MSJobs-UX>

SUNNYVALE, CA

Applied Scientist: Utilize knowledge in applied statistics and mathematics to handle large amounts of data using various tools. <https://bitly.com/MSJobs-Research>

Machine Learning Scientist: Design and deliver general and/or domain-specific machine learning algorithms and systems. <https://bitly.com/MSJobs-Research>

CAMBRIDGE, MA

Data Scientist: Manipulate large volumes of data, create new and improved techniques and/or solutions for data collection, management and usage. <https://bitly.com/MSJobs-Research>

Data Scientist II: Manipulate large volumes of data, create new and improved techniques and/or solutions for data collection, management and usage. Requires international and domestic travel up to 25%. Multiple positions available. <http://www.jobs-microsoft.com/job/go/240636200/> <http://www.jobs-microsoft.com/job/go/240618500/>

CHARLOTTE, NC

Support Engineers / Escalation Engineers: Provide technical support on issues experienced with Microsoft technologies. <http://bit.ly/MSJobs-Support>

Solution Specialist - EPG Core Solution Specialist - CnE or Other: Enhance the Microsoft customer relationship from a capability development perspective by articulating the value of our services and solutions and identifying competition gaps in targeted accounts. Requires travel up to 30% with work to be performed at various unanticipated worksites throughout the U.S. <http://www.jobs-microsoft.com/job/go/240610400/>

NEW YORK, NY

Consultants: Deliver design, planning, and implementation services that provide IT solutions to customers and partners. Roving Employee—requires travel up to 100% with work to be performed at various unknown worksites throughout the U.S. <http://bit.ly/MSJobs-SysOps>

Technology Solutions Professional, Productivity-EPG Core Account Coverage or Other: Drive product win rates by proving the value of product(s) to customers and partners. Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/237832000/>

Technology Solutions Professional-EPG Core Solution Specialist - CnE or Other: Drive product win rates by proving the value of product(s) to customers and partners. Requires travel to local client site(s) up to 50%, and at various unknown worksites throughout the U.S. up to 25%. Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/235646300/>

FARGO, ND

Support Engineers / Escalation Engineers: Provide technical support on issues experienced with Microsoft technologies. <http://bit.ly/MSJobs-Support>

Senior Technical Advisor-Global Business Support or Other: Mentor support partners on technical support issues, process issues, delivery and problem solving processes. <http://www.jobs-microsoft.com/job/go/240354600/>

IRVING, TX

Support Engineers / Escalation Engineers: Provide technical support on issues experienced with Microsoft technologies. <http://bit.ly/MSJobs-Support>

Technical Account Manager-Premier COGS or Other: Assure productive use of Microsoft technologies, focusing on delivering quality through planning and governance. Telecommuting permitted up to 20%. <http://www.jobs-microsoft.com/job/go/240348300/>

Technical Advisor - Global Business Support or Other: Provide technical support on issues experienced with Microsoft technologies. <http://www.jobs-microsoft.com/job/go/237642900/>

Premier Field Engineer: Provide technical support to enterprise customers, partners, internal staff or others on mission critical issues experienced with Microsoft technologies. Requires travel up to 70% with work to be performed at various unknown worksites throughout the U.S. <http://www.jobs-microsoft.com/job/go/240694300/>

IRVINE, CA

Premier Field Engineers: Provide technical support to enterprise customers, partners, internal staff or others on mission critical issues experienced with Microsoft technologies. Requires travel up to 25% with work to be performed at various unknown worksites throughout the U.S. Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/239297000/>

Premier Field Engineers: Provide technical support to enterprise customers, partners, internal staff or others on mission critical issues experienced with Microsoft technologies. Requires travel up to 50% with work to be performed at various unknown worksites throughout the U.S. Telecommuting permitted. Multiple positions available. <http://www.jobs-microsoft.com/job/go/239275900/> <http://www.jobs-microsoft.com/job/go/239110000/>

ALPHARETTA, GA

Technology Solutions Professional DATAPLAT - EPG Core Solution Specialist - CnE or Other: Enhance the Microsoft customer relationship from a capability development perspective by articulating the value of our services and solutions and identifying competition gaps in targeted accounts. Requires travel up to 50% with work to be performed at various unanticipated worksites throughout the U.S. Telecommuting permitted. <http://www.jobs-microsoft.com/job/go/237636800/>

Multiple job openings are available. To view detailed job descriptions and minimum requirements, and to apply, visit the website address listed. EOE.

MICROSOFT CORPORATION currently has the following openings (all levels, e.g., Principal, Senior and Lead levels): Fort Lauderdale, FL and Reno, NV - Business/Operations Program Managers: Responsible for the design, implementation, and release of programs or projects. <http://bit.ly/MSJobs-ProgMgr>. Redmond, WA - Supportability Program Manager – Sales-Consumer or Other: Coordinate program development of computer software applications, systems or services. <http://www.jobs-microsoft.com/job/go/239298500/>. Multiple job openings are available. To view detailed job descriptions and minimum requirements, and to apply, visit the website address listed. EOE.

MICROSOFT CORPORATION currently has the following openings (all levels, e.g., Principal, Senior and Lead levels):

Boulder, CO; Durham, NC; and San Francisco: Software Dev. Engineers, Software Dev. Engineers in Test, Dev. Leads, Software Engineers, Software Engineering Lead and Test Engineers/Leads: Responsible for developing or testing computer software applications, systems or services. <http://bit.ly/MSJobs-SDE>. Redmond, WA: Research Software Development Engineers (all levels): Responsible for conducting applied research into new products and services through software engineering techniques. <https://bitly.com/MSJobs-Research>. Wilsonville, OR: Research Software Development Engineer - Large Screen Devices or Other: Participate in software and system-level design of our controllers for large capacitive touch and stylus sensors. <http://www.jobs-microsoft.com/job/go/240376900/>. Multiple job openings are available. To view detailed job descriptions and

minimum requirements, and to apply, visit the website address listed. EOE.

OPTIMIZATION-BASED SOFTWARE COMPANY providing solutions for transportation scheduling and logistics problems has the following openings in Gainesville, FL: **Senior Systems Engineer** (3) - Conducts research on network and heuristic optimizations; leads algorithmic development team; develops prototypes. Ph.D. (or Master's and 2 yrs. exp. in the field) in Ops. Research, Comp. Sci., Indus. & Systems Eng., or related field req'd. **Systems Engineer** (1) - Develops prototypes for optimization and simulation based solutions. Master's (or Bachelor's, or for. equiv., and 5 yrs. progressive exp. in the field) in Ops. Research, Comp. Sci., Indus. & Systems Eng., or related field req'd. **Senior Software Engineer** (1) - Leads software development; Designs, implements and tests software solutions, algorithms, and data structures. Ph.D. (or Master's and 2 yrs. exp. in the field) in Comp. Sci., Ops. Research, Indus. & Systems Eng., or related field req'd. **Software Engineer** (1) - Designs, implements and tests software solutions, algorithms, and data structures. Master's (or Bachelor's, or for. equiv., and 5 yrs. progressive exp. in the field) in Comp. Sci., Ops. Research, Indus. & Systems Eng., or related field req'd. Salary commensurate with exp. Full-time. Mail resume to: HR, Innovative Scheduling, LLC., 7600 NW 5th Place, Gainesville, FL 32607.



GRADUATE STUDY AT UCF IN ORLANDO

Computer Science at the University of Central Florida (UCF) is looking

for graduate students who are motivated to conduct cutting-edge research and pursue excellence. Successful applicants will be offered 5 years of support (assuming satisfactory progress) in the form of either a Graduate Teaching Assistantship or Graduate Research Assistantship. These positions will be providing financial support, including tuition waivers, and competitive stipends. US citizens are highly encouraged to apply.

UCF is located in Orlando FL — "The City Beautiful." Orlando has hosted several major academic conferences in recent years, including ACM Multimedia. UCF is the largest university in the United States by undergraduate enrollment and the country's second-largest by total enrollment. Both Orlando and UCF have grown from supporting the space program to supporting a thriving high-technology industry, including many software startups.

Computer Science at UCF is performing ground-breaking research in a wide range of research areas, including computer vision, image and video processing, machine learning, AI, virtual reality, HCI, computer graphics, software engineering and systems, database, parallel computation, networking and mobile computing, computer security, bioinformatics and

systems biology, theory, algorithms, and quantum computing. See <http://www.cs.ucf.edu>.

These research areas have been sponsored by federal government agencies and local governments, as well as established close collaborations with the leading companies such as Google, Sarnoff, Microsoft, IBM, GE, and Siemens. The Computer Science program has internationally-recognized faculty, including 5 Fellows of the IEEE.

We are also very proud of many of our students' achievements, for example, National Collegiate Cyber Defense Championship, a prestigious national award for cybersecurity in 2014, and successfully competing at the World Finals of the Association of Computing Machinery's International Collegiate Programming Contest.

REQUIREMENTS

- A Bachelor degree or the equivalent in Computer Science or related majors,
- Excellent academic credentials demonstrated by GPA scores, and competitive GRE test scores.
- Prior publications and an MS degree in CS (or a related area) are a plus.

How TO APPLY:

All applications must be submitted online at <http://www.students.graduate.ucf.edu/gradonlineapp/>.

TECHNICAL LEAD F/T (POUGHKEEPSIE, NY) Position involves travel to various unanticipated worksites up to 100% of the time anywhere in the United States. Must have Bach deg or the foreign equiv in Comp Sci, Comp Appls, or related w/5 yrs of progressive exp or a Master's deg or the foreign equiv in Comp Sci, Comp Appls, or related w/1 yr. exp in gathering requirements from Business Analysts, preparing analysis, design and implementation. Manage and Lead a team of 3 to 5 developers in application analysis, design, development, implementation and testing of software applications through full product development life cycle and release process. Provide project plan estimation and rollout strategy in collaboration with the project manager. Mentor the junior team members by providing technology knowledge transition. Create design documents, technical specifications, class diagram flow-chart based on requirements session. Manage production tickets workload among developers and resolve them

Apple Inc. has the following job opportunities in Cupertino, CA:

ASIC DESIGN ENGINEER (REQ# 9DCPXF). Dev & Execute Functional and Microarchitecture test plans at unit level & full-chip level.

SOFTWARE ENGINEER APPLICATIONS (REQ#9MT2GK). Research, des, dvlp, implement & debug big data reporting platform.

SOFTWARE DEVELOPMENT ENGINEER (REQ#9FN2W3). Des & dev video coding and processing algorithm and SW.

SOFTWARE DEVELOPMENT ENGINEER (REQ# 99YM9C) Perform Cell Cert & Signal conform test for GSM/UMTS/LTE on iOS Cell prod.

SOFTWARE DEVELOPMENT ENGINEER (REQ#9BX267). Design & develop SW for speech recognition systems.

SYSTEM DESIGN ENGINEER (REQ#9993CD) Perform RF Sys-level valid of consumer elect products. Travel req. 20%.

ENGINEERING PROJECT LEAD (REQ#9EZQEY). Resp for the overall tech schedule and milestones for display technologies.

SOFTWARE ENGINEER APPLICATIONS (REQ#9KJMVM). Respon for the research, design, develop, implement & debug of a big data report platform.

SOFTWARE ENGINEER APPLICATIONS (REQ#9MBQ5F). Respon for design & develop of apps on iOS & Mac

OS X for IT systems.

SOFTWARE ENGINEER APPLICATIONS (REQ #9KBPPR). Respon for design & build new svcs platform to provide core svcs to Sales & Mktg apps.

SOFTWARE DEVELOPMENT ENGINEER (REQ#9GQ4Q3). Qualify the next gen of iOS Motion features while collaborating w/ various cross functional teams.

SOFTWARE ENGINEER APPLICATIONS (REQ#9HGQWG). Responsible for security of systems in production.

SOFTWARE DEVELOPMENT ENGINEER (REQ#9E5UET) Dsgn, dvlp, trblshoot, and debug SW prgrms.

iMESSAGE ENGINEER (REQ# 999T6Q). Respon for design & develop of Messages app on all Apple platforms (iOS, Apple Watch & Mac).

BUSINESS SYSTEMS ANALYST (REQ#9K32HE). Develop process or apps that address specific business needs.

ENGINEERING PROJECT MANAGER (REQ#9KK2M7). Manage the dev and implementation of various IT & related apps.

SOFTWARE ENGINEER, APPLICATIONS (REQ#9G2P2S). Des & dvlp web-based solns for Apple Retail Business.

HARDWARE DEVELOPMENT ENGINEER (REQ#9GXVN7). Research,

des, dvlp & conduct state of the art camera image quality measurements & test procedures, practices & methods.

SR. SAP ABAP DEVELOPER (REQ# 9CYLEE). Perform requirements gathering, planning, project execution of SAP design & development. Prepare high level design & prototypes.

SOFTWARE ENGINEER APPLICATIONS (REQ# 9GBPFU). Design & develop SW for Apple's customer systems group.

SOFTWARE QUALITY ASSURANCE ENGINEER (REQ#9JNQSG). Define & create test approaches, plans & automation.

SOFTWARE ENGINEER APPLICATIONS (REQ#9L9475). Perform SAP performance testing, troubleshooting, & tuning.

INFORMATION SYSTEMS ENGINEER (REQ#9DCSU6). Des, dev, implement, & maintain EAI, Internet & J2EE app systems.

SOFTWARE ENGINEER APPLICATIONS (REQ #9H627P). Respon for design & develop of WWDR's web-based apps using Java & J2EE related tech.

FIRMWARE ENGINEER (REQ# 9LUS7A) Rsrch, arch, dsgn, dvlp, implmnt, debug, and maintain firmware/software for embedded microproc-based consumer electronic prdcts.

REFER TO REQ# & MAIL RESUME TO

Apple Inc., ATTN: L.M., 1 Infinite Loop 104-1GM, Cupertino, CA 95014.

Apple is an EOE/AA m/f/disability/vets.

in timely fashion. Provide subject matter expertise and implement the code using following tools/technologies: Java/J2EE, JSF, Spring, Hibernate, EJB, AJAX, Oracle, DB2, Liferay Portal Server, Web Services, Java Script, JQuery, Maven, LDAP, RAD, Eclipse. Send resume: Indotronix Int'l Corp., Recruiting (BC), 331 Main St, Poughkeepsie, NY 12601.

NMS/OSS INTEGRATION SOLUTION ARCHITECT F/T (POUGHKEEPSIE, NY) Position involves travel to various unanticipated worksites up to 100% of the time anywhere in the United States. Must have Bach deg or the foreign equiv in Engg, Comp Sci Engg, Electrical & Electronics engg,

or related w/5 yrs of progressive exp or a Master's deg or the foreign equiv in Engg, Comp Sci Engg, Electrical & Electronics engg, or related w/1 yr. exp in administering, developing and maintaining NMS systems and associated services. Lead NMS/OSS solution re-engineering, including evaluation, selection, integrate and deployment of next generation solutions though N-tier Client Server Technologies in Java, C++ on distribute computing platforms using RMI, CORBA. Resolving service impacting incidents and provide Tier 2 and Tier 3 support during business and non-business hours. Identify, monitor and report NMS application performance using KPIs. Collaborate with

internal and external stakeholders for incident, problem & change management. Test, Validate & deploy enhancements and bug fixes including in-house and vendor delivered patches, hotfixes and service packs. Expert Knowledge required in Tools/Technologies : Java/J2EE, Java Web Services, C, C++, Network Management Protocols SNMP, TL1, NMS, Expert Knowledge of FCAPS, XML, XSLT, AJAX, MySQL, Distributed Computing CORBA, RMI, Working with Web Servers Tomcat, WebLogic. Java Swing/AWT and Oracle, Informix Experience is plus. Respond timely to issues reported. Send resume: Indotronix Int'l Corp., Recruiting (SV), 331 Main St, Poughkeepsie, NY 12601.

CAREER OPPORTUNITIES

ENGINEERING. Paragon Solutions, Inc. is accepting resumes for the position of Senior Developer in Cranford, NJ. Involved in various phases of the Software Development Life Cycle (SDLC) such as requirement gathering, design, analysis, and code development. May require travel to various unanticipated work locations throughout the U.S. Mail resume to Paragon Solutions, Inc., Attn: Staffing, 25 Commerce Drive, Suite 100, Cranford NJ 07016. Must reference Ref. SD-NJ.

ENGINEERING. Highfive Technologies, Inc. is accepting resumes for the position of Software Engineer in Redwood City, CA. Apply deep expertise in the algorithms and systems for the delivery of real time audio and video over the internet. Mail resume to Highfive Technologies, Inc., Staffing Department, 500 Arguello Street, Suite 300, Redwood City, CA 4063. Must reference Ref. SE-MD.

BMC SOFTWARE INC. has the following openings in San Jose, CA: Sr. Product Developer (Req#14003664) to drive, design, development & implementation of Cloud LifeCycle. Requires 10% domestic/int'l travel; Sr. Product Developer

(Req#15000217) to create installers for key products & code, debug & fix defects across products of solutions. Mail resume to Attn: (Req# of interest), BMC Software, Inc., 91 East Tasman Drive, San Jose, CA 95134-1618

BMC SOFTWARE INC. has an opening for Principal Consultant in Houston, TX (or can work office from home anywhere in the U.S.) to analyze and design client middleware system architecture & generate DevOps implement. Plan using BMC and BSA. Requires 75% domestic/int'l travel. Mail resumes to Attn: Req #15000216, BMC Software, 91 East Tasman Drive, San Jose, CA 95134-1618

BT CONFERENCING, INC. has an opening for Lead QA Engineer in Braintree, MA to adapt existing test strategies or develop new ones for incoming product design & solutions in the telecom industry. Requires Bach. + 6 yrs exp. in application testing or QA. Interested applicants mail resumes to Attn: Req#20811, BT Conferencing, 30 Braintree Hill Office Park, Suite 301, Braintree, MA 02184

HCL AMERICA, INC. has the following openings in multiple locations.

Travel & work @ various unanticipated client sites as assigned:

BUSINESS ANALYSTS: Transform business requirements into functional specifications, focusing on workflow analysis & design, business process reengineering, user interface design, & process flow modeling. **Cary, NC:** Reqs BS*+0 (HCL187); BS+2 (HCL188); MS+1/BS+5 (HCL189). **Frisco, TX:** Reqs BS*+0 (HCL190); BS+2 (HCL191); MS+1/BS+5 (HCL192). **Redmond, WA:** Reqs BS*+0 (HCL193); BS+2 (HCL194); MS+1/BS+5 (HCL195). **Sunnyvale, CA:** Reqs BS*+0 (HCL196); BS+2 (HCL197); MS+1/BS+5 (HCL198). **Jersey City, NJ:** Reqs BS*+0 (HCL199); BS+2 (HCL200); MS+1/BS+5 (HCL201).

DATABASE ADMINISTRATORS: Install, configure, maintain, build, & back-up databases. **Cary, NC:** Reqs BS*+0 (HCL202); BS+2 (HCL203); or MS+1/BS+5 (HCL204). **Frisco, TX:** Reqs BS*+0 (HCL205); BS+2 (HCL206); MS+1/BS+5 (HCL207). **Redmond, WA:** Reqs BS*+0 (HCL208); BS+2 (HCL209); MS+1/BS+5 (HCL210). **Sunnyvale, CA:** Reqs BS*+0 (HCL211); BS+2 (HCL212); MS+1/BS+5 (HCL213). **Jersey City, NJ:** Reqs BS*+0 (HCL214); BS+2 (HCL215); MS+1/BS+5 (HCL216).



TEMASEK RESEARCH FELLOWSHIP (TRF)

A globally connected cosmopolitan city, Singapore provides a supportive environment for a vibrant research culture. Its universities Nanyang Technological University (NTU), National University of Singapore (NUS) and Singapore University of Technology and Design (SUTD) invite outstanding young researchers to apply for the prestigious TRF awards.

Under the TRF scheme, selected young researchers with a PhD degree have an opportunity to conduct and lead defence-related research. It offers:

- A 3-year research grant of up to S\$1 million commensurate with the scope of work, with an option to extend for another 3 years
- Postdoctoral or tenure-track appointment (eligibility for tenure-track will be determined by the university)
- Attractive and competitive remuneration

Fellows may lead, conduct research and publish in these areas:

- Advanced Protective Materials
- Cyber Security
- Machine Intelligence
- Photonics Engineering
- Visual and IR Technologies

For more information and application procedure, please visit:

NTU – http://www3.ntu.edu.sg/trf/index_trf.html
NUS – <http://www.nus.edu.sg/dpr/funding/trf.html>
SUTD – <http://www.sutd.edu.sg/trf>

Closing date: 27 April 2015 (Monday)

Shortlisted candidates will be invited to Singapore to present their research plans, meet local researchers and identify potential collaborators in September 2015.

ADVERTISER INFORMATION • MARCH 2015

Advertising Personnel

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Phone: +1 214 673 3742
Fax: +1 888 886 8599

Northeast, Midwest, Europe,
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d.schissler@computer.org

Phone: +1 508 394 4026
Fax: +1 508 394 1707

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Southeast:
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Email: h.buonadies@computer.org
Phone: +1 973 304-4123
Fax: +1 973 585 7071

Advertising Sales Representative (Classified Line & Jobs Board)

Heather Buonadies
Email: h.buonadies@computer.org
Phone: +1 201 887 1703

NETWORK ADMINISTRATORS: Analyze, design, troubleshoot, implement, maintain, & manage network solutions. **Cary, NC:** Reqs BS*+0 (HCL217); BS+2 (HCL218); MS+1/BS+5 (HCL219). **Frisco, TX:** Reqs BS*+0 (HCL220); BS+2 (HCL221); MS+1/BS+5 (HCL222). **Redmond, WA:** Reqs BS*+0 (HCL223); BS+2 (HCL224); MS+1/BS+5 (HCL225). **Sunnyvale, CA:** Reqs BS*+0 (HCL226); BS+2 (HCL227); MS+1/BS+5 (HCL228). **Jersey City, NJ:** Reqs BS*+0 (HCL229); BS+2 (HCL230); MS+1/BS+5 (HCL231).

PROGRAMMER ANALYSTS: Define, develop, code, & test programs & applications. **Cary, NC:** Reqs BS*+0 (HCL232); BS+2 (HCL233); MS+1/BS+5 (HCL234). **Frisco, TX:** Reqs BS*+0 (HCL235); BS+2 (HCL236); MS+1/BS+5 (HCL237). **Redmond, WA:** Reqs BS*+0 (HCL238); BS+2 (HCL239); MS+1/BS+5 (HCL240). **Sunnyvale, CA:** Reqs BS*+0 (HCL241); BS+2 (HCL242); MS+1/BS+5 (HCL243). **Jersey City, NJ:** Reqs BS*+0 (HCL244); BS+2 (HCL245); MS+1/BS+5 (HCL246).

SOFTWARE ENGINEERS: Involved with software implementation, design, testing, & coding. **Cary, NC:** Reqs BS*+0 (HCL247); BS+2 (HCL248); MS+1/BS+5 (HCL249). **Frisco, TX:** Reqs BS*+0 (HCL250); BS+2 (HCL251); MS+1/BS+5 (HCL252). **Redmond, WA:** Reqs BS*+0 (HCL253); BS+2 (HCL254); MS+1/BS+5 (HCL255). **Sunnyvale, CA:** Reqs BS*+0 (HCL256); BS+2 (HCL257); MS+1/BS+5 (HCL258). **Jersey City, NJ:** Reqs BS*+0 (HCL259); BS+2 (HCL260); MS+1/BS+5 (HCL261).

SYSTEMS ANALYSTS: Define systems strategy & develop systems requirements. **Cary, NC:** Reqs BS*+0 (HCL262); BS+2 (HCL263); or MS+1/BS+5 (HCL264). **Frisco, TX:** Reqs BS*+0 (HCL265); BS+2 (HCL266); MS+1/BS+5 (HCL267). **Redmond, WA:** Reqs BS*+0 (HCL268); BS+2 (HCL269); MS+1/BS+5 (HCL270). **Sunnyvale, CA:** Reqs BS*+0 (HCL271); BS+2 (HCL272); MS+1/BS+5 (HCL273). **Jersey City, NJ:** Reqs BS*+0 (HCL274); BS+2 (HCL275); MS+1/BS+5 (HCL276).

INDUSTRIAL ENGINEERS: Design, develop, test, & evaluate integrated systems for industrial production processes. **Cary, NC:** Reqs BS*+0 (HCL277); or BS+2 (HCL278). **Frisco, TX:** Reqs BS*+0 (HCL279); BS+2 (HCL280). **Redmond, WA:** Reqs BS*+0 (HCL281); BS+2 (HCL282). **Sunnyvale, CA:** Reqs BS*+0 (HCL283); BS+2 (HCL284). **Jersey City, NJ:** Reqs BS*+0 (HCL285); BS+2 (HCL286).

PROJECT MANAGERS: Responsible for managing, planning, coordinating, supervising & directing IT professionals. **Cary, NC:** Reqs MS+1/BS+5 (HCL287). **Frisco, TX:** Reqs MS+1/BS+5 (HCL288). **Redmond, WA:** Reqs MS+1/

BS+5 (HCL289). **Sunnyvale, CA:** Reqs MS+1/BS+5 (HCL290). **Jersey City, NJ:** Reqs MS+1/BS+5 (HCL291). *Employer will accept a combination of education & experience as determined by a qualified evaluation service as equivalent to a Bachelor's degree. Multiple job openings are available. How to apply: Mail resume, referencing HCL job code, including job history, to: HCL America, Inc., Attn: ISG Department, 330 Potrero Ave, Sunnyvale, CA 94085. HCL is an Equal Opportunity Employer.

HCL AMERICA, INC. has the following openings in multiple locations. Travel & work @ various unanticipated client sites as assigned:

SALES ENGINEERS: Responsible for selling various IT services to clients & pre-sales engineering support & guidance to customers. **Cary, NC:** Reqs BS*+0 (HCL292); BS+2 (HCL293); MS+1/BS+5 (HCL294). **Frisco, TX:** Reqs BS*+0 (HCL295); BS+2 (HCL296); MS+1/BS+5 (HCL297). **Redmond, WA:** Reqs BS*+0 (HCL298); BS+2 (HCL299); MS+1/BS+5 (HCL300). **Sunnyvale, CA:** Reqs BS*+0 (HCL301); BS+2 (HCL302); MS+1/BS+5 (HCL303). **Jersey City, NJ:** Reqs BS*+0 (HCL304); BS+2 (HCL305); MS+1/BS+5 (HCL306).

BUSINESS DEVELOPMENT MANAGERS: Responsible for business development, discussions, planning, & product development, & working towards connecting & building relationships with key decision makers in customer organizations. **Cary, NC:** Reqs MS+1/BS+5 (HCL307). **Frisco, TX:** Reqs MS+1/BS+5 (HCL308). **Redmond, WA:** Reqs MS+1/BS+5 (HCL309). **Sunnyvale, CA:** Reqs MS+1/BS+5 (HCL310). **Jersey City, NJ:** Reqs MS+1/BS+5 (HCL311).

GENERAL & OPERATIONS MANAGERS: Coordinate business initiatives & integrate people processes across the company, & spearhead development, communication, & implementation of effective growth strategies & processes. **Cary, NC:** Reqs MS+1/BS+5 (HCL312). **Frisco, TX:** Reqs MS+1/BS+5 (HCL313). **Redmond, WA:** Reqs MS+1/BS+5 (HCL314). **Sunnyvale, CA:** Reqs MS+1/BS+5 (HCL315). **Jersey City, NJ:** Reqs MS+1/BS+5 (HCL316).

SALES MANAGERS: Responsible for sales operations in the area of infrastructure management, managing & directing sales operations, & carrying out business development. **Cary, NC:** Reqs MS+1/BS+5 (HCL317). **Frisco, TX:** Reqs MS+1/BS+5 (HCL318). **Redmond, WA:** Reqs MS+1/BS+5 (HCL319). **Sunnyvale, CA:** Reqs MS+1/BS+5 (HCL320). **Jersey City, NJ:** Reqs MS+1/BS+5 (HCL321).

SENIOR MARKET RESEARCH ANALYSTS: Conduct market research &

price comparisons, & analyze market data to identify the competition, target groups, & market opportunities. **Frisco, TX:** Reqs MS+1/BS+5 (HCL322). *Employer will accept a combination of education and experience as determined by a qualified evaluation service as equivalent to a Bachelor's degree. Multiple job openings are available. How to apply: Mail resume, referencing HCL job code, including job history, to: HCL America, Inc., Attn: ISG Department, 330 Potrero Ave, Sunnyvale, CA 94085. HCL is an Equal Opportunity Employer.

EGENCIA, LLC. Currently has openings for the following opportunities in our Bellevue, WA office (various/levels/types): **Software Engineers:** (728.1519) Design, implement, and debug software for computers including algorithms and data structures. **Software Engineers:** (728.1234) Implement software solutions defined by program management by architecting, designing, and writing production quality code. **Software Engineers:** (728. SWE-EG) Design and implement powerful, highly scalable, and reliable applications. Translate functional specifications into logical, component-based technical designs. Send your resume to: Egecia/Expedia Recruiting, 333 108th Avenue NE, Bellevue, WA 98004. Must reference position and Job & Job ID# listed above.

TECHNOLOGY. ItsOn, Inc. has the following job opportunity available in Redwood City, CA: Sr. Web Developer: Architect and re-implement the front-end aspects for the SDC (Service Design Center) platform. Mail resume to: Attn: HR Recruiting, ItsOn, Inc, 3 Lagoon Drive, Suite 230, Redwood City, CA 94065. Must include reference number WEBD-RC.

SAP LEAD. Multiple openings for the following position in Syracuse, New York, and unanticipated client locations throughout the U.S. Design, implement and execute technical project plans for SAP systems. Recommend new strategies and solutions for successful implementation of large Information Technology projects. Develop application solutions and enhancements that meet user requirements and follow development standards. Travel and relocation possible to unanticipated client locations across the U.S. Please mail resume, salary history and position applied for to: Orange Information Technology Solutions, Inc., Attn: Archana Sivakuri, HR Manager, 499 S Warren Street, Suite 504, Syracuse, New York 13202

BMC SOFTWARE INC. has an opening for Sr. SQA Engineer in San Jose, CA to maintain test cases for internal BMC product development lifecycles & conduct test case reviews with developers & project managers. Mail resumes to Attn: Req #15000297, BMC Software, 91 East Tasman Drive, San Jose, CA 95134-1618

BMC SOFTWARE INC. has an opening for Sr Consultant in Houston, TX to install, configure & customize Remedy ITSM products to meet customer reqs. Requires 75% domestic travel to various & unanticipated client sites throughout the US. Mail resumes to Attn: Req #14003264, BMC Software, 91 East Tasman Drive, San Jose, CA 95134-1618

IT PROFESSIONALS: Established IT company has multiple openings for the following: Software Engineer (Lead) & Programmer Analyst (BS or equiv. in CS, Engg. (any) or related & 24 mo. of relevant industry exp.) Solutions Architect (BS or equiv. in CS, Engg. (any), Bus or related & 24 mo. of relevant industry exp.) Quality Assurance Analyst (BS deg. or equiv. in CS, Engg. (any) or related & 24 mo. of relevant industry exp.)

salesforce.com, inc.

has the following positions
open in **Herndon, VA:**

Senior Database Engineer (Ref. #N14J32): Design, build and deploy highly available, robust, resilient, secure and supportable solutions. Use backup and recovery best practices to ensure systems are protected from data loss in compliance with established business continuity.

Senior Program Architect (Ref. #N14S20): Advise and work jointly with Key Customer executives to develop roadmap and strategy to maximize value of salesforce.com investment. Option to work remotely up to 30% from Mid-Atlantic (Washington, DC) region. Domestic travel to unanticipated sites up to 50%.

Mail resume to salesforce.com, inc., P.O. Box 192244, San Francisco, CA 94119. Resume must include Ref. #, full name, phone #, email address & mailing address. salesforce is an Equal Employment Opportunity & Affirmative Action Employer.

Will consider candidates w/combination of education &/or work exp. considered to be equiv. to the mentioned BS degrees & 24 months' of relevant industry exp. for these positions. Lead Software Developers & IT Project Managers, (MS deg. or equiv. in CS, Engg. or related & 12 mo. of relevant industry exp. Sr. Solutions Architect (MS deg. or equiv. in CS, Engg., Bus. or related & 12 mo. of relevant industry exp. We will consider applicants with a relevant bachelor's deg. & significant industry exp. (5 years) for these positions. Positions based out of company's US HDQ in New York, NY & subject to relocation to various unanticipated sites throughout the US. Send resumes to HR Dept., Majesco, 5 Penn Plaza, New York, NY 10001.

SOFTWARE ARCHITECTS (PEGA) sought by established IT firm to perform requirements gathering functions, object oriented analysis, architecture, design, development, testing and implementation functions for various business applications using BPM software incl PEGA. Qualified applicants will have an MS degree or the equiv. in Comp Sci & Engg. or related, and 24 months of relevant industry exp. as a Software Architect/Developer (PEGA) or related; and exp. with PEGA, Oracle, WebSphere, Weblogic, Java, JSP Servlets, DB2 and Scrum technical environments. Positions located in New York, NY with relocation to various unanticipated locations throughout the US. Send resume to: Tata Consultancy Services, 9201 Corporate Blvd., Suite 320, Rockville, MD 20850 (Attn: A. Jindal).

COMPUTERS: Tech Mahindra (Americas) Inc. is seeking to fill numerous IT positions. Prgrm Mgrs to oversee & manage mult. IT projects, proj. planning, dvlpmnt, implementation, acct & delivery mgmt; Proj. mgrs to oversee & manage IT teams w/dvlpmnt of various sftwre apps. Sys. Analyst/Programmers/Quality & Tech Architect /Quality Engg /Test Eng/Sftwre Eng. / Systems Admin/DBAs to analyze, design, dvlp, test & maintain comp software apps through all phases of sftwre dvlpmnt life cycle (Sftwre Eng. may also lead a team on various projects). Mech. Eng (CAD/CAM) to design, develop, validate & perform structural calculations, product improvement, & provide tech. support to design teams at high levels utilizing specific mech. tools. Sales Eng/Bus. Analyst/ Mgmt Analyst for solutions/pre-sales activities w/relev. industry exp. IT Bus. Dev. Mgrs to create new business, negotiate contracts & dvlp proposals for customized IT solutions. Rel. Mgrs to manage/outsource commercial IT/

Eng. deals, monitor & maintain existing accts. All Tech/Mgrial. positions require a MS or BS degree or equiv. in CS, IT. Eng or closely related fields. All mgrial positions requires MS or BS degree or equiv. in CS, IT, CIS, Eng , Bus mgmt/ admin or closely related field & relevant industry exp; Sales/Rel.Mgrs. require a MS or BS degree or equiv. in Bus. Admin or Eng. & relev. Industry exp. Positions are based out of corp. HQ in 4965 Preston Park Blvd, # 500, Plano, TX 75093 & subject to travel & relocation to client sites located throughout the U.S. Mail resume & position applied for w/JOB CODE: 03IE15 to RMG, Tech Mahindra (Americas) Inc., 1001 Durham Ave, Ste 101, South Plainfield NJ 07080.

SENIOR GIS SOFTWARE ENGINEERS sought by Osceola Consulting headquartered in Tiburon, CA, to design/dvlp/implement/support GIS & similar software as tech & functionl lead. Min req's: Bachelor's degree or foreign academic equiv. in Comp Sci or Mech Eng or closely related field, plus 5 yrs of work exp as Software Eng, Developer, or Project Lead. Work to be done at various unanticipated work sites in southern CA, incl but not limited to San Diego county. May reside anywhere in USA. Travel expenses reimbursed. Send resume and cover letter referencing job ID:012215 to: K. Narcomey, Osceola Consulting, One Blackfield Dr, Ste 110, Tiburon, CA 94920

HOTWIRE, INC. currently has openings for the following opportunities in our San Francisco, CA office (various/levels/types): •Software Engineers: (728.SWE) Design, implement, and debug software for computers including algorithms and data structures. •Managers, Test (728.965) Manage onsite QA test team responsible for functional testing of various Hotwire application verticals or decoupled products. Send your resume to: Hotwire/Expedia Recruiting, 333 108th Avenue NE, Bellevue, WA 98004. Must reference position and Job & Job ID# listed above.

APPLE INC. has the following job opportunities in Austin, TX: *ASIC Design Engineer [Req#9EW22D]. Respon for the pre-silicon verification of embedded graphics cores.*ASIC Design Engineer [REQ#9E52QR]. Carry out phys implementation of 1 or more complex SOC blcks from netlist to tape-out in adv technology nodes. Refer to Req# & mail resume to Apple Inc., ATTN: L.M., 1 Infinite Loop 104-1GM, Cupertino, CA 95014. Apple is an EOE/AA m/f/ disability/vets.

salesforce.com, inc.

has the following positions open:

In San Francisco, CA:

Enterprise Data Warehouse Support Engineer (Ref. #N14501): Responsible for analyzing systems, designing Business Objects, Informatica architecture and Production support.

Senior Member of Technical Staff, Quality Engineering (Ref. #N14507): Design, enhance, and maintain test automation frameworks and write code to automate test cases in order to increase the efficiency of testing.

Member of Technical Staff, Quality Engineering (Ref. #N14508): Design and Develop the ETL code using Informatica. Remote work opportunity up to 40% of the time

Product Management Manager (Ref. #N14509): Own the platform encryption product lifecycle: researching market opportunities and pain points; building roadmap; defining how the product will work; and shepherding it through to completion. Position requires up to 25% domestic and international travel to unanticipated sites.

Senior Manager, Technology Compliance (Ref. #N14510): Ensure controls are appropriately designed and operating effectively and efficiently.

Senior Technical Consultant (Ref. #N14511): Analyze, design, and optimize business processes via technology and integration, including leadership in guiding customers and colleagues in rationalizing and deploying emerging technology for business use cases.

Senior Business Analyst, Oracle Finance Systems (Ref. #N14517): Define, clarify needs, architect and build system solutions for business requirements and map solutions for financial applications on Oracle financials.

IT Platform Specialist, Hyperion Systems (Ref. #N14503): Provide recommendations/solutions regarding processes to facilitate system stability, maintenance and flexibility utilizing Hyperion systems functionality, including Hyperion Financial Management, Hyperion Planning, Hyperion Essbase, Hyperion Financial Reporting, Hyperion Financial Data Quality Management, Hyperion EPMA, Hyperion Financial Close Management, and Hyperion Smartview.

Network Engineer (Ref. #N14502): Analyze, design, test, install, document, implement and support of the global converged network.

Senior Manager, Quality Engineering (Ref. #N14521): Manage multiple teams of highly technical QA Engineers who work in 100% automated test environment.

Manager, Quality Engineering (Ref. #N14522): Manage multiple teams of technical QA Engineers who ensure product quality by focusing on design, implementation and test automation.

Senior Manager, IT Platform Specialist (Ref. #N14524): Responsible for operational processes to provide end-to-end production support of internal company enterprise system implementations. Position requires domestic and/or international travel up to 10%, to meet with staff in other regional sites.

Senior Member of Technical Staff, Software Engineering (Ref. #N14525): Identify missing test cases and refine existing scripts for modularity and automation purposes, estimate and prioritize work for optimal risk mitigation and identify suitable regression suites.

IT Platform Specialist (Ref. #N14527): Provide global production support by overseeing dynamic queue of support cases logged by business end users related to Oracle Financials, and resolve technical cases with strong analytical and functional troubleshooting skills.

Senior Member of Technical Staff, Software Engineering (Ref. #N14528): Responsible for investigating architectural, design, and implementation issues for large customer implementations, and consulting on solutions. Remote work opportunity. Position can be based anywhere in the U.S. Position requires domestic and/or international travel up to 5% to unanticipated client sites.

Associate Member of Technical Staff, Quality Engineering (Ref. #N14529): Under the direction and supervision of senior technical staff, perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Manager, Quality Engineering (Ref. #N14530): Manage teams of technical engineers who write test plans, write test code and execute test cases in both manual and automated environments.

Member of Technical Staff, Software Engineering (Ref. #N14531): Responsible for developing code (Java, SQL) that will provide effective and efficient testing and monitoring of our on-demand business software platform.

Member of Technical Staff, Software Engineering (Ref. #N14533): Design and implement new features to enable feature parity between Oracle Advanced Queuing and Apache Qpid.

Senior Manager, Product Management (Ref. #N14534): Leverage market analysis, competitive knowledge, and customer research to define the roadmap to drive the success of the company's core Case Management product. Position requires domestic and/or international travel up to 20% of the time to unanticipated client sites.

Software Engineer, Member of Technical Staff (Ref. #N14535): Design and develop solutions on Force.com platform that runs commerce processes, using Java, Apex programming language and Visual Force MVC.

Senior Systems Engineering Engineer (Ref. #N14537): Contribute to the overall success of the IT Operations organization by providing oversight and improvement of corporate IT infrastructure platform and by streamlining recurring administrative efforts.

Senior Member of Technical Staff, Quality Engineering (Ref. #N14538): Utilize extensive prior experience to perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Manager, Software Engineering (Ref. #N14539): Manage multiple teams of technical Engineers to provide technical guidance, career development, and mentoring.

Senior Member of Technical Staff (Ref. #N14540): Design and develop ETL code using Informatica.

Senior Program Architect (Ref. #N14541): Serve as a Trusted Advisor, driving conversations with customer's Enterprise Architects and Business Stakeholders armed with best practices for enterprise architecture functions such as Security, Performance, Development Process, and Application Governance. Remote work opportunity. Position can be based anywhere in U.S. Domestic travel up to 70% required.

IT Senior Systems Engineer (SSO) (Ref. #N14542): Perform infrastructure service design and implementations, perform analysis and optimization, monitor and resolve problems, upgrade planning and execution, and process creation and documentation.

Software Engineer, Associate Member of Technical Staff (Ref. #N14543): Design, and develop solutions on Force.com Platform-as-a-Service, using Apex programming language and Visual Force MVC.

Software Developer (Ref. #N14544): Design and develop new stories using Apex, Visual Force, CSS, Sauce Labs, Selenium, and Java Script.

Associate Member of Technical Staff, Quality Engineering (Ref. #N14545): Under the direction and supervision of senior technical staff, perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Senior Member of Technical Staff, Quality Engineering (Ref. #N14546): Utilize extensive prior experience to perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Senior Developer (Ref. #N14547): Implement Android-based application software and components while collaborating with other developers and designers on site architecture, design, and implementation. Remote work opportunity position can be based anywhere in the U.S. Requires 25% domestic and international travel.

Member of Technical Staff, Quality Engineering (Ref. #N14548): Perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Member of Technical Staff, Quality Engineering (Ref. #N14550): Create test plans and test case using test case management system.

Mail resume to salesforce.com, inc., P.O. Box 192244, San Francisco, CA 94119. Resume must include Ref. #, full name, phone #, email address & mailing address.

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has the following positions open:

In San Francisco, CA:

Member of Technical Staff (Ref. #N14551): Design and develop Pig and Hive scripts.

Product Security Engineer (Ref. #N14552): Security ownership for one or more product areas and/or acquisitions, including security design, architecture, feature testing, and final security review.

Associate Localization Program Manager (Ref. #N14553): Utilize cultural knowledge regarding business practices and cultural preferences in terms of communication and user interface interaction to translate and adapt software for foreign markets. Assist software developers in designing and writing software UI string that conform to localization best practices, in particular for Simplified Chinese.

Sr. Member of Technical Staff, Quality Engineering (Ref. #N14555): Utilize extensive prior experience to perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Associate Member of Technical Staff, Quality Engineering (Ref. #N14556): Under the direction and supervision of senior technical staff, perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Associate Member of Technical Staff, Quality Engineering (Ref. #N14557): Under the direction and supervision of senior technical staff, perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Member of Technical Staff, Quality Engineering (Ref. #N14559): Perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Member of Technical Staff, Quality Engineering (Ref. #N14560): Perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical and functional specifications.

Senior Network Engineer (Ref. #N14561): Analyze, design, test, install, document, implement and support a global converged network.

Database Developer (Ref. #N14J21): Maintain the company's data warehouse and operational data store by supporting the overall data model and optimizing for performance.

Release Engineer (Ref. #N14J08): Build, configure, and administer highly complex core applications and multiple products. Support and collaborate with various technical teams of Quality Engineering, System Engineering and Product Managers.

Release Engineer (Ref. #N14J20): Build, configure, and administer highly complex core applications and new products. Provide technical support to hundreds of developers, quality engineers, system engineers, and product managers on the company development infrastructure, processes, and technical application.

Associate Member of Technical Staff, Performance Engineering (Ref. #N14J24): Analyze, understand, and improve company performance from server generation to browser rendering.

Member of Technical Staff, Performance Engineering (Ref. #N14J43): Design and implement overhead, scalability, stability, and stress tests using industry standard tools and custom developed software.

Member of Technical Staff, Software Engineering (Ref. #N14J22): Research and develop current state of software identity, authentication, security, and development.

Associate Member of Technical Staff, Performance Engineering - Sales Cloud (Ref. #N14J23): Research and profile application in order to provide recommendation on improvements to the performance of features. Build scalable and sustainable performance tools and framework for generating load and analyze results automatically.

Associate Member of Technical Staff, PerfEng - Service Cloud (Ref. #N14J06): Analyze, understand, and improve the company's performance from server generation to browser rendering. Design complex tests for analysis of scalability, reliability, and performance of distributed, large-scale systems.

Senior Member of Technical Staff (Ref. #N14J18): Develop, design, and test automation for features. Use company platform to build features.

Account Executive, Commercial Business (Ref. #N14J14): Target, identify, and close new business opportunities. Oversee customers daily to address potential client satisfaction issues. May require travel to various unanticipated locations throughout the U.S.

Senior Member of Technical Staff, Performance Automation and Tools (Ref. #N14J07): Develop architected code to provide insights in company scalable cloud offerings, diagnose problems rapidly and improve performance.

Sales Engineer (Ref. #N14J52): Work with Commercial Sales Account Executives on new and existing accounts. Understand customer goals and challenges and establish the company's products as the best solution available.

Manager, Sales Operations (Ref. #N14J49): Utilize understanding of software design and engineering to design better technical solutions for our clients and to redesign existing systems to improve business efficiency.

Sales Strategy Manager (Ref. #N14J50): Perform direct business partner support to the leader of the Independent Software Vendor and Channel Management division.

Category Manager, Technology (Ref. #N14J51): Serve as liaison between Global Strategic Sourcing, the business, and the Technical Operations and IT communities.

Category Manager, Strategic Sourcing (Ref. #N14J53): Collect data, conduct market analysis and spend analysis and provide reporting data to determine economic forecast market trends. Require travel up to 15% to various unanticipated locations throughout the U.S.

Documentation Productivity Manager (Ref. #N14J04): Coach and mentor a team of Engineers for professional development. Work with the Doc Tools teams to roll out new tools, process improvements, and communication enhancements that improve the productivity of the Documentation team.

Senior Marketing Operations Analyst (Ref. #N14J41): Gather numbers, track, and analyze efforts in support of the marketing organization.

Database Engineer (Ref. #N14J64): Design, build, and deploy highly available, robust, resilient, secure, and supportable database environments.

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has the following positions open:

In San Francisco, CA:

Associate Member of Technical Staff (Ref. #N14J31): Write and review source code using standard industry tools and computer languages.

Senior Member of Technical Staff, Software Engineering (Ref. #N14J55): Develop high-quality, production ready code. Develop tools and methods to facilitate automation efforts.

Member of Technical Staff, Apex (Ref. #N14J11): Collaborate with product owners, customers and other developers to design, develop and test software applications, platforms, automation frameworks, and tools.

VirtualPod API Developer (Ref. #N14J37): Develop and own major parts of company infrastructure. Responsible for backend and web-service development.

Associate Member of Technical Staff (Ref. #N14J29): Formulate, implement, and evaluate algorithms for platform and application features. Code for both back end and front end development.

Senior Software Engineer (Ref. #N14J40): Responsible for web or platform development with web technologies. Develop using standard industry tools and computer languages.

Associate Member of Technical Staff (Ref. #N14J25): Develop, design, and test automation for features by utilizing multiple computer languages and tools.

Associate Member of Technical Staff (Ref. #N14J26): Responsible for design, development, unit testing, and integration testing using multiple software engineering tools and languages.

Product Manager (Ref. #N14J67): Communicate data integration product specifications to engineers during product development. Document data integration use cases and acceptance criteria.

Member of Technical Staff (Ref. #N14J30): Ensure customer success by delivering high quality features and products. Improve company development processes and code base. Write automated tests for code developed.

Senior Member of Technical Staff, Application Development (Ref. #N14J46): Develop high-quality software code and fix defects and performance issues.

Senior Member of Technical Staff (Ref. #N14J59): Design and implement search algorithms to power the company's core technology infrastructure and facilitate scalable high-performance applications

Senior Member of Technical Staff (Ref. #N14J03): Analyze applications and systems for performance bottlenecks. Evaluate bottlenecks and prototypes and best resulting enhancements and configuration changes to tune applications and servers.

Member of Technical Staff, Software Development Engineer (Ref. #N14J65): Develop features for search and implement features for the company's search experience. Resolve technical issues and drive innovation that improves search scalability, relevancy, and user experience.

Senior Member of Technical Staff (Ref. #N14J01): Develop and enhance existing infrastructure and framework using Force.com programming.

Associate Member of Technical Staff, Software Engineering (Ref. #N14J63): Formulate, implement, and evaluate algorithms for platform and application features. Code in JavaScript, HTML, and CSS for front-end development.

Member of Technical Staff, Software Engineering (Ref. #N14J28): Analyze, design, and develop highly useful, high quality software. Perform code reviews.

Lead Member of Technical Staff, Software Engineering (Ref. #N14J54): Lead the design and implementation effort for significant features developed as part of the server based synchronization service between the company's and external mail servers.

Sales Strategy Manager (Ref. #N14J60): Liaise with Senior Management around the world to develop communication plans that will align worldwide sales teams.

ISV Account Manager (Ref. #N14J62): Provide sales enablement for existing partners. Perform Go-To-Market planning (business, marketing, and pricing) with partners. Create new pipeline through engagement of more challenging accounts.

Vice President, Platform (Ref. #N14J09): Oversee the design and development of software according to functional and technical design specifications.

Principal Sales Engineer (Ref. #N14J10): Understand strategic customer goals and challenges to distill into business requirements.

Associate Sales Engineer (Ref. #N14J38): Help customers evaluate salesforce platform by leading technical discussions and delivering product demonstrations.

Accounting Operations Manager (Ref. #N14J61): Monitor the status and progression of Corporate Accounting initiatives and projects, and communicate their status to management as appropriate.

Manager, CSG Strategy & Operations (Ref. #N14J66): Design, build, and maintain executive-level presentations with strategic insights based on statistical and analytical data.

Technical Program Manager (Ref. #N14J12): Create custom web application to enable salesforce developer marketing efforts.

In San Mateo, CA:

Technical Developer Support Engineer (Ref. #N14S04): Assist third-party developers to troubleshoot their integration with the company's APIs, Apex, Visualforce and implementation of other company developer products.

MySQL Database Administrator (Ref. #N14J36): Setup and configure MySQL database servers in various topologies on Linux environments.

Senior Member of Technical Staff - Performance Engineering (Ref. #N14J35): Design and implement overhead, scalability, stability, and stress tests using industry standard tools and custom developed software.

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has the following positions open in **Indianapolis, IN**:

Software Engineer (Ref. #N14J13): Design, develop, and maintain application code to meet design specifications.

Software Engineer (Ref. #N14J16): Implement and gather requirements based on design specifications. Provide maintenance support on existing code.

Senior QA Automation Engineer (Ref. #N14J15): Build automation test suite based on design specifications, requirements, wireframes in agile environment based on sprint planning and short release cycles.

Senior Software Quality Automation Engineer (Ref. #N14J34): Build automation test suite based on design specifications, requirements, or wireframes in an agile environment based on sprint planning and short release cycles.

Software Engineer (Ref. #N14J42): Utilize industry standard tools to develop, design, and implement high-quality code.

Senior Software Engineer (Ref. #N14J33): Responsible for the design, development, and production support of internal and external applications.

Senior Member of Technical Staff, Software Engineering (Ref. #N14J45): Play a pivotal role in the development of new features and the maintenance and enhancement of existing features of company products.

Software Engineer (Ref. #N14J44): Implement and gather requirements based on design specifications. Provide maintenance support on existing code.

Manager, Platform Specialists (Ref. #N14S06): Responsible for managing a team to support dynamic queue of support cases and projects related to back office financial systems with an emphasis on Oracle eBusiness Suite. Participate in weekly on-call rotation. Must be available during off hours approximately one week per month.

Senior Member of Technical Staff, Quality Engineering (Ref. #N14S12): Utilize extensive prior experience to perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Member of Technical Staff, Quality Engineering (Ref. #N14S13): Perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Sr. SQA Security Engineer (Ref. #N14S14): Utilize extensive prior experience to perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Member of Technical Staff, Quality Engineering (Ref. #N14S15): Perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

Senior Member of Technical Staff, Quality Engineering (Ref. #N14S16): Utilize extensive prior experience to perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

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has the following position
open in **Tampa, FL:**

Senior Member of Technical Staff

(Ref. #N14J03)

Analyze applications and systems for performance bottlenecks. Evaluate bottlenecks and prototypes and best resulting enhancements and configuration changes to tune applications and servers.

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has the following position
open in **Atlanta, GA:**

Senior Member of Technical Staff, Software Engineering

(Ref. #N14J19)

Design and develop features and services using standard industry tools. Improve architecture and optimize performance of complex software systems.

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has the following position
open in **New York, NY:**

Senior Technical Architect

(Ref. #N14S05)

Validates customer's technical design and solution. Develops specialties in ExactTarget date management, scripting languages, API, and/or integrations.

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has the following position
open in **Santa Monica, CA:**

Member of Technical Staff, Quality Engineering

(Ref. #N14S54)

Perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

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has the following position
open in **Seattle, WA**:

**Senior Member Technical
Staff, Quality Engineering**
(Ref. #N14S26)

Utilize extensive prior experience to perform functional manual and/or automated testing of features, including writing detailed testing plans and relevant test cases to cover business use cases, error handling and boundary conditions as defined in technical specifications.

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has the following position
open in **Palo Alto, CA**:

**Senior Member of
Technical Staff,
Data Science**
(Ref. #N14J58)

Lead efforts across teams to design and implement major core components of search, cache, and big data processing infrastructure.

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Samsung Research America, Inc.

has the following opportunities
available in **Mountain View, CA**:

Staff Software QA Engineer (Ref# SJ15A01):

Execute manual or scripted testing at functional and system levels on enterprise software products.

Software Engineer (Ref# MTV15B01):

Develop test plans for GPU verification and create graphics programs and tests.

Sr. Software Engineer (Ref# MTV15B02):

Create test cases covering all aspects of mobile testing and take responsibility for product quality.

Interaction Designer, Staff 2 (Ref# MTV15B03):

Develop design prototypes ranging from comps to interactive mock-ups and visual interface specifications.

Specific requirements apply.

Mail resume referencing job title
and Ref# to farhat.k@samsung.com.

Linkedin Corp. has openings in our **Mountain View, CA** location for:

Software Engineer (All Levels/Types) (6597.671, 6597.997, 6597.576, 6597.906, 6597.1028, 6597.258, 6597.85, 6597.1000, 6597.1037) Design, develop & integrate cutting-edge software technologies; **Engineering Manager (6597.52)** Work with Hadoop to data mine high quality profile data & search query logs to gain insights around search relevance; **Associate User Experience Designer (6597.708)** Design solutions that address business, brand & user requirements; **Data Services Operations Engineer (6597.689)** Serve as a primary point responsible the overall health, performance & capacity of our back-end Hadoop based data warehouse environment.

Linkedin Corp. has openings in our **Sunnyvale, CA** location for:

Software Engineer (All Levels/Types) (6597.541, 6597.1006, 6597.907, 6597.1024, 6597.632, 6597.843, 6597.804) Design, develop & integrate cutting-edge software technologies; **Technical Program Manager (6597.713)** Support product development teams in building software products and tools to deliver company business objectives.

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Call for Papers

Special Issue on Pattern Recognition

For *IEEE Intelligent Systems'* Nov/Dec 2016 issue

Submission Deadline: 25 May 2015

Pattern Recognition (PR) is one of the key abilities in human and machine intelligence, and an important branch of the more broad area of Artificial Intelligence (AI). Pattern recognition endows machines the ability of environmental perception, while cognition (including reasoning, knowledge engineering, and language understanding), is addressed by other branches of AI. PR and AI are often interwoven in intelligent systems (for example, the perceptron process exploits knowledge to solve ambiguities in recognition). The scope of Pattern Recognition includes pattern classification (statistical and structural PR, neural networks, kernel methods, ensemble methods, etc.), clustering, feature extraction and selection, data pre-processing (such as image processing and segmentation), visual object recognition, video analysis, applications in document analysis, biometrics, medical imaging, remote sensing image analysis, multimedia, video surveillance, intelligent transportation, and so on. Methods and applications have both seen tremendous advances in recent years. For example, deep learning methods have boosted performance in many fields such as handwriting recognition, facial recognition, speech recognition, traffic sign recognition, and so on.

This special issue aims to report on and discuss the state of the art in pattern recognition theory and applications—particularly, new ideas, methods, and innovative applications. The topics of interest include, but are not limited to:

- Cognitive mechanism and mathematical foundation of PR

- Pattern classification
- Feature extraction and selection
- Machine learning for pattern recognition
- Object detection and recognition
- Image and Video analysis
- Applications in document analysis, biometrics, data mining, intelligent transportation, etc.

Submission Guidelines

Submissions should be 3,000 to 5,400 words (counting a standard figure or table as 200 words) and should follow *IEEE Intelligent Systems* style and presentation guidelines (www.computer.org/intelligent/author). The manuscripts cannot have been published or be currently submitted for publication elsewhere.

We strongly encourage submissions that include audio, video, and community content, which will be featured on the IEEE Computer Society Website along with the accepted papers.

Guest Editors

- Cheng-Lin Liu, Institute of Automation of Chinese Academy of Sciences, China
- Brian Lovell, University of Queensland, Australia
- Dacheng Tao, University of Technology Sydney, Australia
- Massimo Tistarelli, University of Sassari, Italy

Questions?

- **Information about the special issue's focus:**
Peng Cui, is6-2016@computer.org
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discipline brings its own priorities to the table. Students must learn to recognize the value in these sometimes conflicting approaches and come up with strategies for collaborating and resolving differences constructively.

Being a part of the development process also helps students hone listening skills. In meetings and collaborative interactions, they must extract from what others are saying the information they need to operate productively, asking pertinent questions when necessary and “hearing” what might not be stated explicitly. Understanding context and identifying critical problem areas others might miss

are invaluable when developing solutions.

Finally, students develop a sense of responsibility because each individual’s actions affect the team’s overall result. Team members must accurately estimate and report how much they can accomplish within a given week as they juggle school and other obligations, allowing the team to plan ahead. As with any group effort, one member failing to deliver on time can cause the team to fall behind schedule.

The UWB Digital Future Lab helps student teams develop the confidence

and competence required to work as professionals in the gaming industry and beyond. For more information, visit www.bothell.washington.edu/digitalfuture. ☺

Adapted from Fernando Arnez, Jason Pace, and Kelvin Sung, “Learning while Building Games for Teaching,” Computer, vol. 47, no. 4, 2014.



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ACM and the IEEE Computer Society co-sponsor the **Eckert-Mauchly Award**, which was initiated in 1979. The award is known as the computer architecture community’s most prestigious award.

The award recognizes outstanding contributions to computer and digital systems architecture. **It comes with a certificate and a \$5,000 prize.**

The award was named for John Presper Eckert and John William Mauchly, who collaborated on the design and construction of the Electronic Numerical Integrator and Computer (ENIAC), the first large-scale electronic computing machine, which was completed in 1947.

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Time Is Money

So what's the overall "worth" of these various contributions? Let's use a simple equation, $T = M$, where T is "time" and M is "money." If you spend, say, 10 hours making placemats to sell on Etsy (a great example of cognitive surplus in action, albeit with a consumer-fueled flair) and sell all of them at a net profit of \$100, the time-to-money conversion rate is simple: \$10 per hour.

It's possible, of course, that those 10 hours of work "felt" less than that because you enjoy making placemats—in which case, the math doesn't precisely hold up. If, on the other hand, making placements becomes a great burden, then the math may reveal that your business model is wrong, that you need to find a way to do less work or charge more per placemat.

The conversion rate gets a little wonky if you're a blogger. (This can involve anything from a YouTube channel where you talk about your favorite Hot Wheels cars to a podcast about 18th-century doilies to a Twitch channel where you speedrun classic video games.) For many, blogging is simply an act of expression—a public diary. If you use a platform that enables ads, then you may regard any revenue as simply the happy byproduct of a pastime you're pursuing anyway.

Distributed Systems and AI to the Rescue?

When you participate in another's act of creation—by leaving a comment on a website, for example—the math gets even murkier. Your conversation (which takes a few minutes) now can theoretically affect the value for the creator—generating ad revenue by increasing the average time on the site, adding to or decreasing the site owner's credibility, and so on.

This spirals into all corners of the Web, where your time—and, in many cases, data—gets converted into dollars. You may not necessarily see the money in the form of currency, but someone

does. And you yourself may, in return, get a better experience—an investment of sorts in the quality of your favorite Web content.

Moreover, we're approaching a digital world where it's not only our human cognitive surpluses that are adding value. A feedback loop of AI-assisted recommendations now feeds on individual patterns and consumer profiles to pop-up with "other books you might like" or "related search results": a Kurzweilian "personal shopper," who knows our every digital move.

In addition to a surplus of human cognitive ability, there's increasingly a surplus of silicon as well. My favorite example is the SETI@home project (<http://setiathome.ssl.berkeley.edu>), which aims to use "excess" computing power from idle machines in the search for extraterrestrial intelligence by mining radio telescope data. It may not have found aliens yet (or maybe it did, and men in black suits and hats are keeping that info from us), but the possibility is made more real by computers "volunteering" in their spare time.

While I'm impressed with such virtual volunteers, the simple fact of sentience changes the nature of volunteering. Choosing where and how to spend "free" time is not only an acknowledgment of value; it's also a privilege, one not available in many parts of the world.

Clearly, many consider volunteering to "foster technological innovation and excellence for the benefit of humanity" (IEEE's mission) a particular privilege—something I (and my colleagues) are both impressed by, and very grateful for. 🍕

Brian Kirk is IEEE Computer Society's associate manager for editorial product development. Contact him at bkirk@computer.org.



Selected CS articles and columns are also available for free at <http://ComputingNow.computer.org>.

We Are All Volunteers Now

Brian Kirk

In my job, I work with a lot of volunteers, many of whom contribute directly to the Computer Society's ever-expanding body of knowledge. Their dedication in helping produce and curate content for our magazines and journals—in addition to maintaining their “day jobs” and a home life—never ceases to amaze me.

I've been wondering, though: What exactly does it mean to be a “volunteer”? The word generally refers to someone doing something for free. But it's not really that simple. Don't volunteers get something in return for their efforts? Or, put another way, shouldn't they get something?

Cognitive Surplus

An amazing thing about the connected world we live in now is our capacity for expression. As members of this post-Web 2.0/post-industrial society, we no longer simply receive information from a select few content providers. Instead, we participate in a “web” of creation. Straddling the line between creator and audience, we each now have the capacity to simultaneously produce and

consume an unprecedented amount of content: “prosumers,” if you will.

Of course, this wouldn't be possible except for what Clay Shirky, in a 2010 book of the same name, called “cognitive surplus.” (His subtitle, *Creativity and Generosity in a Connected Age*, suggests the connection I'm making to volunteerism.) Shirky argues that the move to a (more or less) 40-hour work week gives many in the developed world more “free” time for things like enjoying mass entertainment. As technology has caught up with—and possibly contributed to—innovation in this space, rather than just receiving content passively, we devote more and more of this surplus time to active creation and sharing.

Not only do we enjoy the plethora of YouTube videos uploaded every day (and create our own videos documenting anything we want, as well); we can now point our virtual thumbs up or down, or add our own comments, to the content others have shared—contributing additional “value” (and, in the process, making it easier for all of us to find something worthy of our “free” time).

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