Dear Friends of CITRIS,

Austerity. Budget cuts. Limits. Fiscal cliffs. Nobody likes these things. And yet, if necessity is the mother of invention, then austerity is sometimes the parent of innovation. The two stories profiled in this issue of The CITRIS Signal demonstrate the great progress that can be made when limits are reached but progress must still be made.

The first piece, *The $10 Robots: Irresistible and Affordable*, describes professors Ken Goldberg’s and Ayorkor Korsah’s efforts to spur creativity among robot developers by putting them on a very tight budget. When
I was back at CMU and designing robots for Westinghouse Corp., we felt pretty accomplished if we could come in on budget at $100,000. The limit Ken imposed was a little tighter; the competition he and professor Korsah launched last summer was for robots that could be manufactured for 10 dollars or less. The resulting entries are not just frugal, they are paradigm-defying delights.

Incidentally, the winner of the tethered category sweetened its victory by coming in nearly a dollar and a half short of the ten-dollar budget. That makes it about 1/27th the price of the cheapest programmable educational robot on the market to date. This little guy could make a big difference to budding roboticists in schools around the developing world. Come see an exhibit featuring the little Suckerbot at the Tech Museum at CITRIS Headquarters here in Berkeley.

The second story, Connected Corridors: Deploying the Wisdom of Crowds and Macro-Models to Ease Traffic Woes, hits us close to home. Here in the SF Bay Area, where the commuters among us spend, on average, more than 60 hours standing still in traffic each year, auto congestion is no longer a problem we can simply build and spend our way past. Alex Bayen’s and Roberto Horowitz’s Connected Corridors Project will employ crowd sourced data collection with advanced traffic modeling and prediction technology to help Caltrans better manage the increasing numbers of cars on the road. At millions of dollars per lane mile, we can’t afford to just keep throwing more concrete construction at the problem.

Instead, CITRIS-supported research is adding intelligence to systems that will better coordinate not only the freeway traffic that clogs our urban arteries each weekday, but also the neighboring arterials, employing underused roads to relieve pressure on congested ones. This is made possible by the groundbreaking work of Alex, who was among the first to use GPS-enabled cell phones to provide real-time traffic information, and Roberto, whose macro-modeling techniques make complex traffic analysis possible so these intelligent systems can advise their human overlords on the best possible solution to any traffic problem. This will save commuters time. And it will also save billions in now wasted energy costs and reduce unnecessary pollution and greenhouse gas emissions. Safer, faster, cheaper, cleaner.

Keep up the good work!

Best wishes,

Paul K. Wright
Director, CITRIS
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Kids love robots almost as much as they love candy. Combining the two makes the Suckerbot “irresistible,” says Ken Goldberg, the craigslist Distinguished Professor of New Media at UC Berkeley. The Suckerbot (seen to the right) is a lollipop-decked, wheeled, educational robot entry in the African Robotics Network's $10 Robot Competition. “It is a fresh approach,” says Goldberg.

Fresh, irresistible, and outside the box are what Goldberg and Ayorkor Korsah, an assistant professor of computer science at Ashesi University in Ghana, were looking for when they launched the competition last summer in a search for ways to overcome high prices that have put a crimp on robotics education in the developing world. They were hoping to defy design and material barriers, but they had not thought of adding candy…until this entry, made by Thomas Tilley of Thailand.

While on sabbatical in Ghana last Spring, Goldberg met Korsah and a group of her university students, who were working with Lego Mindstorms robots. “The students were very sophisticated, talented, and smart,” says Goldberg. But because Lego robots cost about $250 each, it was difficult for schools or after-school programs to acquire them without external assistance, and in the quantities needed to work with entire classrooms of students.

There is a thriving marketplace for technology in Ghana. The lively market in refurbished computers meant many Ghanaian students have their own laptops, observed Goldberg. “Roadside stands sell stacks of inexpensive, refurbished, shrink-wrapped IBM laptops that were a few years old but worked fine.” But robots of any kind, let alone inexpensive educational robots, are nowhere to be found in Ghana.

At Ashesi University, Goldberg and Korsah first brainstormed about the value to students of an inexpensive robot. “Since high schools in Ghana are generally under-resourced, an inexpensive robot would go a long way,” Korsah says. “Students would actually be able to purchase the robots and take them home with them extending their learning beyond our classroom,” she says. “Furthermore, our high school partners could build on the
program through robotics clubs and other activities in their schools."

Korsah and Goldberg, who together formed the African Robotics Network (AFRON), launched the $10 Robot Competition in order to plug into the genius for innovation and practical problem solving they see throughout Africa and many other parts of the developing world.

“If Raspberry Pi Computers can sell a unit for $35, then we should be able to get a programmable, school-worthy robot way down from $250,” says Goldberg. “We set a target at $10, but we were willing to consider any proposal below $100.”

At the annual IEEE International Conference on Robotics and Automation in May 2012, Korsah and Goldberg announced the competition and described the prizes that had been donated by Raspberry Pi and the IEEE Robotics and Automation Society. Word of the contest spread fast, as did word about the new African Robotics Network (AFRON) which supports robotics research and education throughout Africa. Six months after its formation, AFRON has more than 300 members.

Korsah and Goldberg wanted to keep the contest’s rules as simple as possible. Contestants had only to track the cost of their materials, to restrict themselves to open-sourced software, and to describe and document their robots in detail on a website. The competition, which accepted entries from June 15 to September 15, was covered in Wired.com (“Can a $10 Robot Save African Education?”) and the IEEE Spectrum (“African Project Aims To Innovate in Educational Robotics”), but still Korsah and Goldberg were uncertain how many people would actually submit robots.

“I do not know how to make a $10 robot. I had no idea where to start,” says Goldberg. “So I was not about to suggest how others should approach it.”

By mid September, AFRON had received 28 entries that were wildly diverse in materials, philosophical approach, country of origin, and design aesthetic. A few were submitted by teams from top institutions like Harvard and MIT, but most from people or groups that roboticists Korsah and Goldberg had never heard of.

The contest had three categories: tethered, roaming, and all-in-one, and an international jury judged all entries. The winners were announced at the Maker Faire in New York City in September. The winner was the Baobot, a modular robot that won second prize in the AFRON contest.
What kid could resist a robot with two functional lollipops? It’s a magnet. The idea is to get kids excited about engineering and science at an extremely low cost.

- Ken Goldberg

Suckerbot, now on display in the CITRIS Tech Museum, won first prize in the tethered robot category. The tether in this case is the USB cable built into a Sony PlayStation game controller that serves as the robot’s body. Thomas Tilley of Thailand picked up the used controller at a surplus store for about $5. He converted the internal vibration motors into drive trains for wheels, which he made from recovered bottle tops. The lollipops, which are stuck into the thumb switches of the controller, act as counterweights. When the unit bumps into something, the lollipops fall forward and send a signal to the controller. A line sensor is patched into the other thumb stick; the robot can be programmed to track along a path. The whole thing is designed to be built from scratch for a total of $8.96, says Tilley’s website, which includes detailed instructions.

“What kid could resist a robot with two functional lollipops? It’s a magnet. The idea is to get kids excited about engineering and science at an extremely low cost,” says Goldberg.

Winning second prize in the tethered category was a modular robot called the Baobot, into which students can plug different sensors to observe and program different behaviors. “The Boabot could be ordered pre-assembled,” says Korsah, “or students can also learn a little about electronics by assembling Boabot from a kit.”

Winner of the roaming category was the Kilobot, a coin-sized robot that uses vibration motors that move it along on smooth surfaces. Kilobots cost about $43 a piece, but their true colors shine only when you have a swarm of them that can communicate with each other and engage in “social” behavior. Kilobots also have onboard light sensors and built in microprocessors which can be programmed in C. The Kilobot’s Harvard team has been working on the robot for years.

The MITBot, submitted by a team in India, won the all-in-one category with a modular kit made of plastic parts that could be configured into a lot of different designs. The cost: $33. That is $217 less than the Lego Mindstorms Robot, also a modular.

“Even our more expensive entries lowered the
price by an order of magnitude,” says Goldberg.

Korsah and Goldberg are now raising money for the competition’s second round in Summer 2013, which will encourage entrants to design software and curricula for the prize-winning robots.

Their hope is that the final product will be manufactured in Africa, say Korsah and Goldberg. If that is going to happen, though, someone will have to act fast; one Chinese company has already expressed interest in manufacturing the Suckerbot. The retail price the company proposed was $50, too much for Korsah’s and Goldberg’s taste. But still, five times less than Lego Mindstorms.

To learn more, see the top placing robots, enter the next competition, or to join AFRON, please visit the AFRON website*. The winning designs will be on display at UC Berkeley in the CITRIS Tech Museum** until March 15, 2013.

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*Find out more at:
http://robotics-africa.org/design_challenge.html

**See the winning robots mentioned in this story:
The CITRIS Tech Museum
Sutardja Dai Hall, 3rd floor
UC Berkeley
Berkeley, CA 94720
Hours: M-F (except holidays) 8:30a-4:30p
(510) 664-4301
Two California urban areas have the dubious distinction of being tied for second-worst traffic in the country. Commuters spend 61 hours per year being stuck in traffic in the Bay Area and in Los Angeles. (First prize goes to Washington, D.C., with an average of 67 hours.) Population and car numbers continue to increase, which means more frustrating hours spent in gridlock, more money lost on wasted energy, and more air pollution. In the past, government agencies across the country would have addressed the crunch by widening highways and building new roads, tunnels and bridges. However, for both financial and space reasons, the emphasis has now shifted from building new infrastructure to more efficient use of what we have already built.

“If you look at the cost-benefit tradeoffs, more efficient operations is a much better deal,” says Alex Bayen, the principal investigator of a new UC-Berkeley based project to boost freeway efficiency.

The project, called Connected Corridors, led by Bayen and his UC Berkeley colleague professor Roberto Horowitz, is developing new technologies that will help Caltrans gather and analyze traffic data to make real-time whole-system traffic management recommendations. Connected Corridors is an outgrowth of two projects: Mobile Millennium, which Bayen launched in 2008 that employed data from mobile-phone-using volunteers to fuel a traffic-mapping application; and Tools for Operational Planning (TOPL), Horowitz’s project that employs novel algorithms to model traffic. Within the next three years, the combined group will implement a prototype traffic-advisory system for a major commuting corridor in California. The project is currently working with Caltrans to determine the best possible location, but a heavily-used corridor in the Los Angeles area is the leading candidate.

Exploiting both Bayen’s ability to gather real-time traffic data and Horowitz’s ability to crunch it, the project will create a modeling program that quickly evaluates traffic
conditions and then recommends the best possible mitigating actions for the agencies that control both the freeway itself and the smaller arterials surrounding it.

“We are not just going to be monitoring traffic, we are also going to be managing it,” says Horowitz, who is director of Partners for Advanced Transportation Technology (PATH), a Berkeley-based institute dedicated to advancing traffic management and traveler information systems.

Because the project requires the coordination not only of huge data sets, but also of multiple state and local agencies, it has a large policy component as well its core technological ones. “If the agencies and governments cannot cooperate and communicate, this will not work,” says Horowitz.

There will be times when the system analysis recommends using metering lights on an entrance ramp to relieve congestion and speed traffic on the freeway. But that relief might come at the expense of, say, a backup of traffic from those metering lights into a commercial or residential district along the highway. Caltrans may be most concerned with relieving traffic for the thousands of cars on the highway, but a city’s government might be more concerned with keeping its own streets flowing smoothly. Coordinating the sometimes conflicting needs and responsibilities of different agencies and governments, and building those potential conflicts of interest into the modeling program, is a significant part of the project, says Bayen, an associate professor of civil and environmental engineering at UC Berkeley.

“We are taking care to address those possibilities upstream,” says Bayen. A decision tree will be built into the modeling advisor, and any actions that would violate agreements between agencies will not be considered among the viable alternatives.

At the traffic managers’ disposal will be a kit of traditional tools to go with some new ones. The group will be controlling metering lights at freeway entrances, occasionally opening shoulders to traffic, coordinating lights on freeway entrances—and those on arterials in neighboring areas as well. They will also employ changeable message signs on the freeway to report general conditions downstream and advise drivers about what is happening ahead in their own lane. All of these management tools will be supercharged by the coordinating and analytical power of the “very, very fast macro-simulation programs” at the heart of the project, says Bayen.
Whereas other traffic-decision-support projects around the country rely on micro-simulation programs that crunch every single piece of data, the Berkeley team addresses the problem at a larger resolution and “faster results that are much easier to optimize,” says Bayen. That means the program can consider all of the alternatives and give real-time advice about the best way to reduce overall congestion in almost any scenario.

Connected Corridors’ software learns with experience, constantly comparing its best predictions with ground-tested reality, says Horowitz. “It continually monitors traffic characteristics and compares them to historical data, makes predictions, and then compares those predictions to actual outcomes and corrects for discrepancies,” says Horowitz. “It will get more and more accurate over time.”

Of course commuters, too, make up a self-calibrating and learning system. Turning that fact to the project’s advantage, Connected Corridors has teamed up with Waze, the prime social network for commuters.

“Traffic information is not only quantitative data, like speed and travel times; It includes aspects of qualitative life not necessarily captured by numbers: people feeling happy about their commute, sharing things about the difficulty of a specific road or the danger of another road.”

On its mobile app, Waze users share real-time information about accidents, road conditions and alternate routes. That data will be fed into the Connected Corridors advisor program, as well. The wisdom of the crowd will complement the genius of the learning imputation algorithm.

For now, the system will strictly be a “decision support system.” It will advise human decision makers in real-time on what to do to improve traffic. Eventually, however, the system could be entirely automated, a “decision control system,” says Horowitz. In fact, when areas covered by computational tools become large, interconnected, and complex enough, it may be impossible for any human to understand, in real time, why a particular traffic management strategy would be optimal.

“Eventually the thing should run on its own,” says Horowitz. “But first we are trying to present the best available information to humans in a way that they can grasp and act upon. We will be very conservative.”
A system that accurately models traffic outcomes will not only be useful on a day-to-day basis for managing existing traffic, but will also be a helpful tool for policymakers trying to predict the consequences of different proposed development projects and infrastructure alterations.

Phase Two of Connected Corridors will include a public transportation component, communicating with drivers about their transit options even as they move toward their destinations. If an accident causes gridlock downstream of a BART station, for example, drivers can be informed where they can find station parking and how much time they could save by shifting out of their cars and into a train.

“Right now we are working on more efficient operations. And then there is nudging people’s behavior,” says Bayen. “That is a little more futuristic, and I do not think we are quite ready for that.”
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Baobot website
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