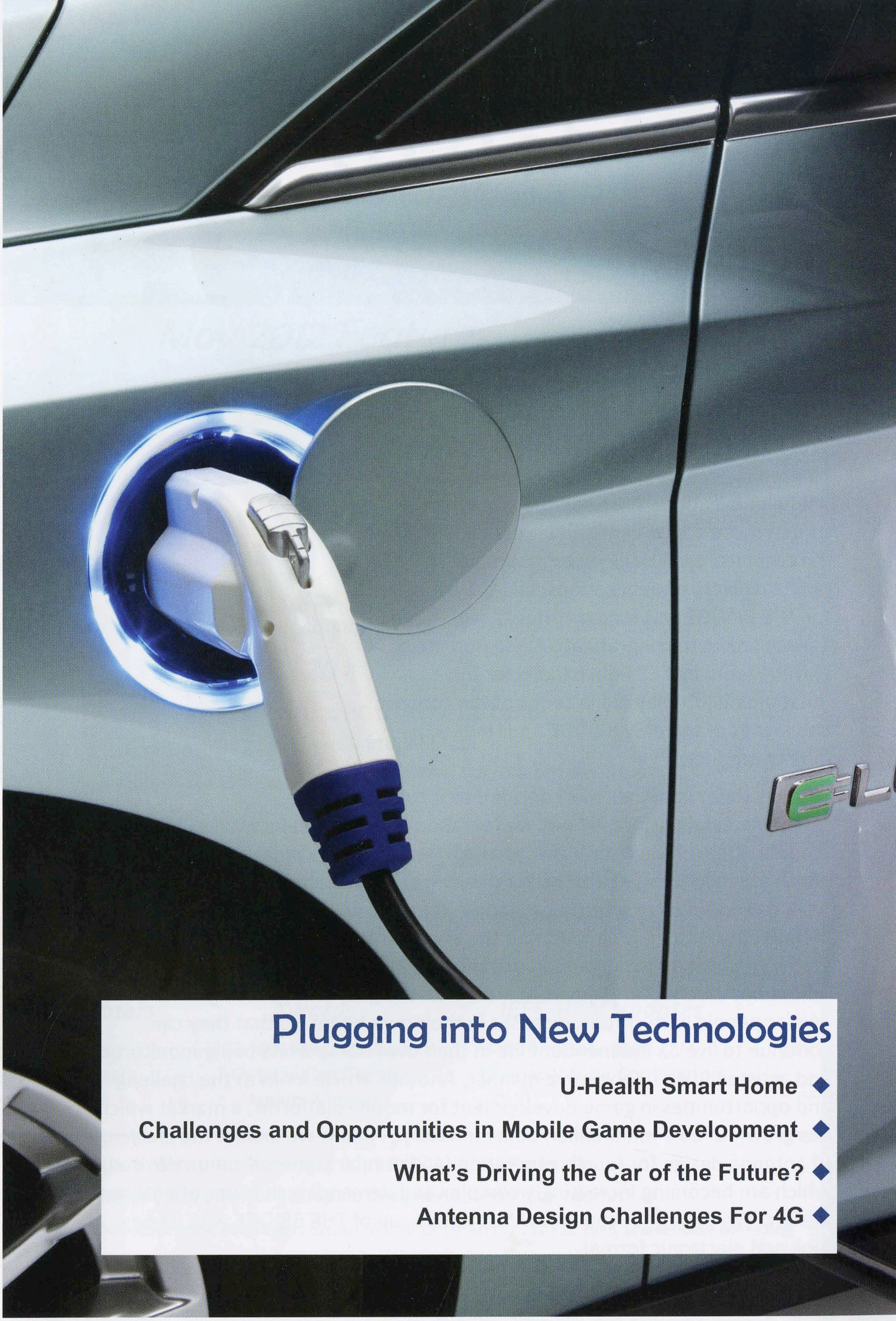
THE • BRIDGE

The Magazine of IEEE-Eta Kappa Nu



Plugging into New Technologies

U-Health Smart Home ◆

Challenges and Opportunities in Mobile Game Development ◆

What's Driving the Car of the Future? ◆

Antenna Design Challenges For 4G ◆

May 2012 Vol. 108 / no. 1

HKN IEEE

LETTER FROM THE PRESIDENT

STEPHEN M. GOODNICK

Pi Chapter

Dear IEEE-HKN Members and Friends:

In this issue of THE BRIDGE, we are introducing a new look and layout for THE BRIDGE. We are pleased to now be delivering THE BRIDGE as an online publication. We hope that you find this format more convenient and accessible. Most of the technical publishing world has moved to online delivery of publications, and the transition for THE BRIDGE was long overdue. I would in particular like to congratulate Alissa Rothstein and the team in IEEE Publications for the outstanding job they did in terms of the content and layout of the new BRIDGE. It is indeed a quality product.

In the present issue, we have decided to focus on several technology innovations we feel should be of keen interest to IEEE-HKN readers. One article details the rapid advances in hybrid vehicle technology, which are increasingly penetrating the conventional automobile market, and have the potential of affecting a transition from fossil fuel to electric vehicle technology, with major impacts on the energy infrastructure of the United States. A second article looks at advances enabled by nanotechnology in ubiquitous care (U-care) smart homes, with the goal of supporting the elderly and/or people with chronic diseases in their own home, so that they can continue to live an independent life in their own home while being monitored and assisted in an unobtrusive manner. Another article looks at the challenges and opportunities in game development for mobile platforms, a market which has grown to be a multi-billion dollar industry. Finally, we look at the challenges of antenna design for fourth generation (4G) cellular communication devices, which are becoming increasingly complex and demanding in terms of antenna design. We hope that you enjoy this latest issue of THE BRIDGE with its new look and electronic format.

Best regards,

Stephen M. Goodnick

IEEE-HKN INTERNATIONAL HEADQUARTERS
Address editorial, subscription, email updates, and address change correspondence to:
IEEE-Eta Kappa Nu
445 Hoes Lane
Piscataway, NJ 08854, USA
+1 732 465 5846
+1 732 465 5808 fax
BRIDGE@hkn.org email
www.hkn.org

THE◆BRIDGE

The Magazine of IEEE-Eta Kappa Nu

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Departments

Production Manager | News and Copy Editor: Alissa Rothstein

Features Editor | Art Director | Graphic Designer: Joanne Van Voorhis

Advertising Sales | Business Development Manager: Susan Schneiderman (+1 732 562 3946, ss.ieeemedia@ieee.org)

IEEE-Eta Kappa Nu (IEEE-HKN) was founded by Maurice L. Carr at the University of Illinois on 28 October 1904, to encourage excellence in education for the benefit of the public. IEEE-HKN fosters excellence by recognizing those students and professionals who have conferred honor upon engineering education through distinguished scholarship, activities, leadership, and exemplary character as students in electrical or computer engineering or by their professional attainments. THE BRIDGE is the official publication of IEEE-Eta Kappa Nu. Ideas and opinions expressed in THE BRIDGE are those of the individuals and do not necessarily represent the views of IEEE-Eta Kappa Nu, the Board of Governors, or the magazine staff.

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(Cover Photo: Courtesy of Ford Motor Company)

LETTER FROM THE EXECUTIVE DIRECTOR

Fern E. Katronesky

Eta – Board of Directors Chapter

Dear IEEE-HKN Members:

It is a pleasure for me to update our readers on some important activities that occurred during this 2011-2012 academic year. We have been in contact with several of our dormant chapters who have expressed interest in reactivating their Chapter, and we are looking to do that with many more this year. We are also working with a number of universities who have expressed interest and would like to start a new chapter on their campus.

In early December 2011, we installed the new IEEE-HKN Lambda Zeta Chapter at the University of North Texas in Denton, Texas, and in late December we began to expand IEEE-HKN into worldwide global boundaries by establishing three international chapters. In January, we installed the IEEE-HKN Lambda Iota Chapter at the University of Hong Kong; in February, the IEEE-HKN Lambda Eta Chapter at the Bharati Vidypeeth's College of Engineering in New Delhi, India; and in March, the IEEE-HKN Lambda Theta Chapter at Dalhousie University in Halifax, Nova Scotia, Canada. We look forward to partnering with our Chapters, and alumni members worldwide, in growing IEEE-HKN.

We are continuously updating our membership database and ask that if you move, you notify Headquarters with your updated contact information. It is very important for us to be able to keep in contact with you as you move through school as an undergraduate or graduate, and then move on into the career you have long awaited to be in. You can provide your changes to BRIDGE@hkn.org and keep your records current.

Thank you for your continued support of IEEE-HKN. We appreciate your contributions. Every gift makes a difference and yours helps to support IEEE-HKN programs. If you would like to contribute to the IEEE-Eta Kappa Nu Restricted Fund, please visit www.ieee.org/donate. We encourage all members to contact Headquarters for opportunities to serve the organization with your time and talents.

We hope you enjoy this issue of THE BRIDGE.

Best regards,

Fern E. Katronetsky

IEEE-HKN AWARD NOMINATIONS

As an honor society, IEEE-Eta Kappa Nu has plenty of opportunities designed to promote and encourage outstanding students, educators and members.

Visit www.hkn.org/awards to view the awards programs, awards committees, list of past winners, nomination criteria and deadlines.

Outstanding Young Electrical and Computer Engineer (OYECE) Award

Presented annually to an exceptional young engineer who has demonstrated significant contributions early in his or her professional career.

Nominations due: 30 September 2012

Vladimir Karapetoff Outstanding Technical Achievement Award

Recognizes an individual who has distinguished him or herself through an invention, development, or discovery in the field of electrical or computer technology.

Nominations: ongoing

Outstanding Electrical and Computer Engineering Student (OECES) Award

Annually identifies an ECE senior who has proven outstanding scholastic excellence, high moral character, and exemplary service to classmates, university, community and county.

Nominations due: 30 June 2012

Outstanding Chapter Award

Singles out chapters that have shown excellence in their activities and service at the department, university and community levels. Winners are determined by their required Annual Chapter Reports for the preceding academic year.

Chapter Reports due: 15 October 2012

C. Holmes MacDonald Outstanding Teaching Award

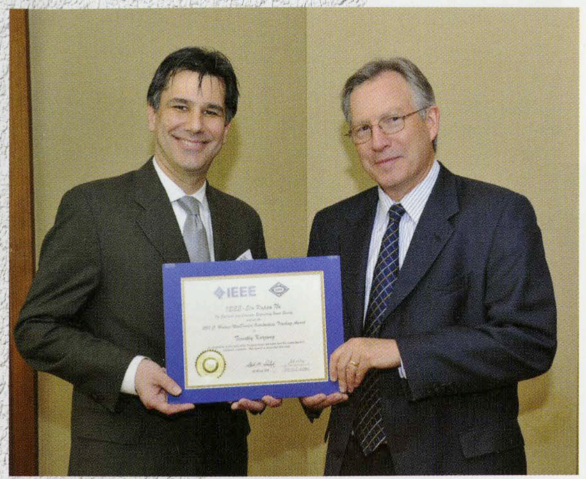
Presented annually to a dedicated young professor who has proven exceptional dedication to ECE education and had found the balance between pressure for research and publications and enthusiasm and creativity in the classroom.

Nominations due: 1 December 2012

C. Holmes MacDonald Outstanding Teaching Award *Presented March 2012*

Timothy Kurzweg

The 2010-2011 C. Holmes MacDonald Outstanding Teacher Award was presented to Dr. Timothy Kurzweg, Associate Professor of Electrical and Computer Engineering; Assistant ECE Department Head for Undergraduate Affairs; and Assistant Dean of Engineering and Director of the Bachelor of Science in Engineering Program of Drexel University. Dr. Kurzweg was chosen as the 2010-2011 faculty award recipient for his dedication to training and motivating future electrical and computer engineers despite the pressure on young professors for research and publication performance. The award is intended to recognize the central and crucial role of college professors in training and motivating future electrical and computer engineers. Two others, Professor David Lambeth and Professor Sayan Mitra, of Carnegie Mellon University and University of Illinois, Urbana-Champaign, respectively, were identified as Honorable Mentions.



2010-2011 Outstanding Teacher Award Winner Timothy Kurzweg is presented his award by IEEE-HKN President Stephen Goodnick (r).

Outstanding Electrical and Computer Engineer Student (OECES) Award *Presented March 2012*

Kathryn Nicole Rodhouse

The 2010-2011 Outstanding Electrical and Computer Engineering Student (OECES) Award was presented to Kathryn Nicole Rodhouse of Missouri University of Science and Technology, with Dana M. Gude of Kansas State University receiving Honorable Mention. Ms. Rodhouse completed her undergraduate work in May 2011, receiving a B.S. in Computer Engineering. She will receive her M.S. degree in May 2012. Ms. Gude received her B.S.E.E. and graduated in May 2011 as well.

2010-2011 OECES Award Winner Kathryn Rodhouse is presented her award by IEEE-HKN President Stephen Goodnick (l) and Kelvin Erickson (r), Department Head, Missouri University of Science of Technology.

2010-2011 OECES Honorable Mention Award Winner Dana Gude is presented her award by IEEE-HKN President Stephen Goodnick (l) and Don Gruenbacher (r), Department Head, Kansas State University.

Outstanding Chapter Award *Presented March 2012*

Congratulations to a record-breaking twenty-four Outstanding Chapter Award winners for the 2010-2011 academic year. The awards are determined by a calculation of service hours, recruiting and retention efforts, and the overall report score. Chapters are required to file the Annual Chapter Report each year by 15 October for the preceding academic year.

2010-2011 Outstanding Chapter Award Recipients:

Beta	Purdue University
Beta Epsilon	University of Michigan – Ann Arbor
Beta Eta	North Carolina State University
Beta Kappa	Kansas State University
Beta Mu	Georgia Institute of Technology
Beta Theta	Massachusetts Institute of Technology
Delta Omega	University of Hawaii, Manoa
Delta Xi	Air Force Institute of Technology
Epsilon Beta	Arizona State University
Gamma Chi	New Mexico State University
Gamma Mu	Texas A&M University
Gamma Rho	South Dakota State University
Gamma Theta	Missouri University of Science and Technology
Gamma Xi	University of Maryland, College Park
Iota Gamma	University of California – Los Angeles
Kappa Psi	University of California – San Diego
Lambda Delta	FAMU – FSU College of Engineering
Mu	University of California – Berkeley
Nu	Iowa State University
Phi	Union College
Rho	University of Colorado at Boulder
Sigma	Carnegie Mellon University
Theta Mu	Stony Brook University
Xi	Auburn University

U-Health Smart Home

Innovative solutions for the management of the elderly and chronic diseases.

By Nazim Agoulmine, M. Jamal Deen, Jeong-Soo Lee, and M. Meyyappan

The elderly population worldwide has been increasing as a result of longer life expectancies, primarily due to the significant improvements in public health, nutrition, and medicine. In the United States, the population above the age of 65 is expected to double by 2040. At the same time, developed societies are facing a new phenomena, such as the increase in the number of people with chronic diseases, such as diabetes, chronic obstructive pulmonary disease, and arthritis. This is not only due to the increasing aging population but also the change of diet and lifestyle in modern societies.

According to the World Health Organization, diabetes is projected to become one of the world's main disablers and killers within the next 25 years. Because of its chronic nature, the severity (and possible fatality) of its complications, and the means required to control them, diabetes is a costly disease not only for the affected individual and his/her family but also for health-care providers.

The management of people with chronic diseases and the elderly is steadily pushing health-care costs upward in a dramatic way that could jeopardize the survivability of any national healthcare system. With these current trends, it will soon be impossible for most governments to fully support their national health-care system without negatively impacting their economies. However, it is possible to reduce this cost by seeking innovative solutions for the management of the elderly and people with chronic diseases using advances in information and communication technologies (ICTs) combined with the potential from emerging areas such as nanotechnology (NT) and biotechnology (BT).

It has been proven that effective prevention of diseases and early detection of health problems help to significantly reduce the cost of health care. It is then necessary to develop new types of devices and protocols to implement these measures as soon as possible. Hence, to reduce the high cost of hospitalization or management in costly specialized institutions, it is necessary to develop new systems that allow the elderly and those with chronic diseases to live safely in their own home. This future home aims to provide self-management-style health and safety services to its inhabitants, e.g., self-health monitoring and medical self-measurements. While the patients will be self-managed for most of the time, the smart home is always connected to a back-end medical institution (e.g., hospital) where doctors are continuously informed about the situation of the smart home inhabitant. Also, through technologies such as game consoles, the inhabitant can be encouraged to practice regular exercise, weight control, and a diet suitable for their chronic condition.

This concept of a ubiquitous healthcare (U-Health) smart home for the elderly has been identified by governments and medical institutions as an important part of the economical, technological, and socially acceptable solution to maintain the health welfare system viable for future generations. Most elderly people are concerned with their health, and they need to spend much to maintain good health; this unfortunate trend has been steadily increasing over the years. Therefore, we are investigating one possible solution: a U-Health smart home system.

U-Health Smart Home at POSTECH

A new generation of a ubiquitous health smart home is being developed at Pohang University of Science and Technology (POSTECH) in Korea by integrating advances in ICT–BT–NT to support the elderly and/or people with chronic diseases in their own home. The goal of the U-Health smart home is to help the elderly to continue to live a more independent life as long as possible in their own home while being monitored and assisted (as much as possible) in an unobtrusive manner. Monitoring is done by a self-managed intelligent system capable of handling in an autonomic way situations that are usually handled by humans. The U-Health smart home is connected via broadband Internet access to back-end health-care providers (e.g., hospitals and specialized institutions) who are continuously informed about the status of the monitored inhabitant for handling emergency situations that necessitate their intervention.

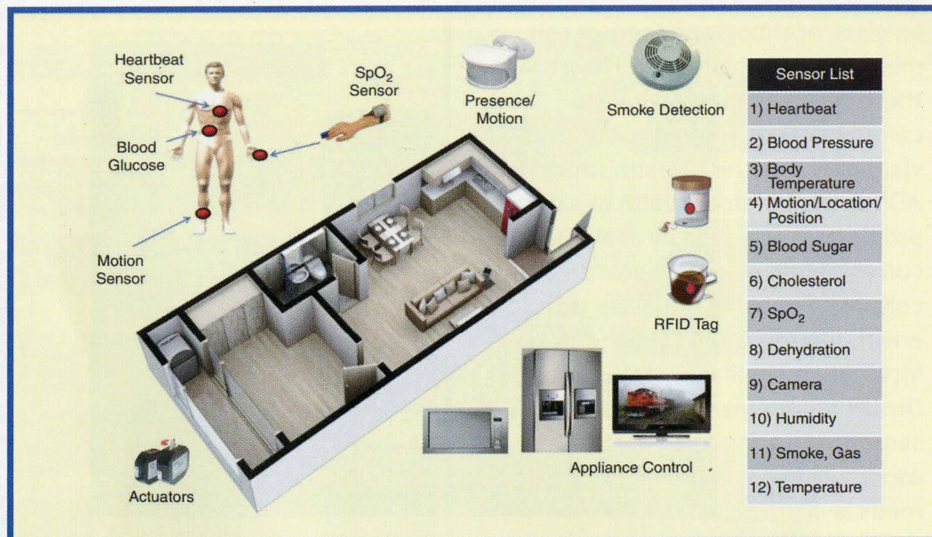


FIGURE 1 Overview of the U-Health system.

The U-Health smart home will provide the inhabitants with a large range of health and safety services that can be upgraded from time to time. The POSTECH U-Health smart home (Figure 1) takes advantage of advances in low power electronics and sensor technologies, which has led to small-sized medical body sensors and actuators that are capable of collecting physiological data from the body of the monitored inhabitant and possibly delivering some drugs. This is done through the deployment of a wireless body area network (WBAN). The solution also introduces a complete home communication network (HCN) and a U-Health autonomic decision making system (ADMS) capable of collecting data from the various context providers in the home (medical body sensors and environment sensors as well as cameras) to build a snapshot of the monitored person's situation and infer the status in terms of health and safety to take appropriate decisions directly in the home, on the body of the monitored person, or by communicating with backend health-care providers (e.g., hospitals). The ADMS should be able to make autonomic decisions for many situations and therefore reduce the cost of human intervention.

FIGURE 2 Autonomic U-Health smart home framework.

Layered Architecture

The functional architecture of the U-Health smart home is composed of four layers, as depicted in Figure 2. Innovation is expected in each layer of this architecture, which is the aim of the POSTECH project. The general requirements at each layer of this architecture are presented below.

Sensors and Actuators

The lower layer consists of two main components: the sensors and actuators. The sensor components are physical devices that collect data about the environment (e.g., temperature, presence, sound, and gas/vapor) and about the health status of the monitored inhabitant (blood pressure, heart rate, and temperature). Actuators are physical devices that allow performing remote action on the environment (e.g., light control and appliance control) or on the monitored inhabitant's body (e.g., drug delivery such as insulin). There are a variety of sensors and devices available for monitoring a patient's health status: e.g., we can find a blood glucose sensor that is capable of continuously monitoring the blood glucose level, and an electrocardiography sensor can measure the activity of the heart. All these sensors can use wireless communication to send data directly or via the HCN to the UHealth smart home ADMS. Detection of health or safety problems is achieved by analyzing and correlating the physiological data collected from these sensors with some environmental information (e.g., localization, appliance status, etc.). Design requirements for these types of sensors and actuators are strict, especially for those addressing the medical needs. The acceptance of such devices by the inhabitants is only possible if they are easy to install or to wear and configure. Also, the devices should introduce as little inconvenience as possible to the patient.

Home Communication Network

The second layer of the framework is the HCN. Data generated by various sensors must be delivered to the ADMS for effective coordination of the actions in the smart home. Deployed sensors and actuators transmit their data either through wireless communication technologies using protocols such as ZigBee, Bluetooth, or Wi-Fi or wired communication technologies such as Ethernet or power line communications. The environmental sensors and actuators using wireless communication form a wireless sensor network (WSN) capable of transporting information from any sensor to a sink connected to the wired home network and vice versa. The WBAN allows the medical sensors and actuators to communicate with a control on short range to receive or send data. A coordinator in the WBAN can directly communicate with some nodes in the WSN and then the wired home network. Using HCN, the ADMS can communicate with any environment and medical sensors to collect data about the context of the inhabitant and remotely perform appropriate actions when necessary.

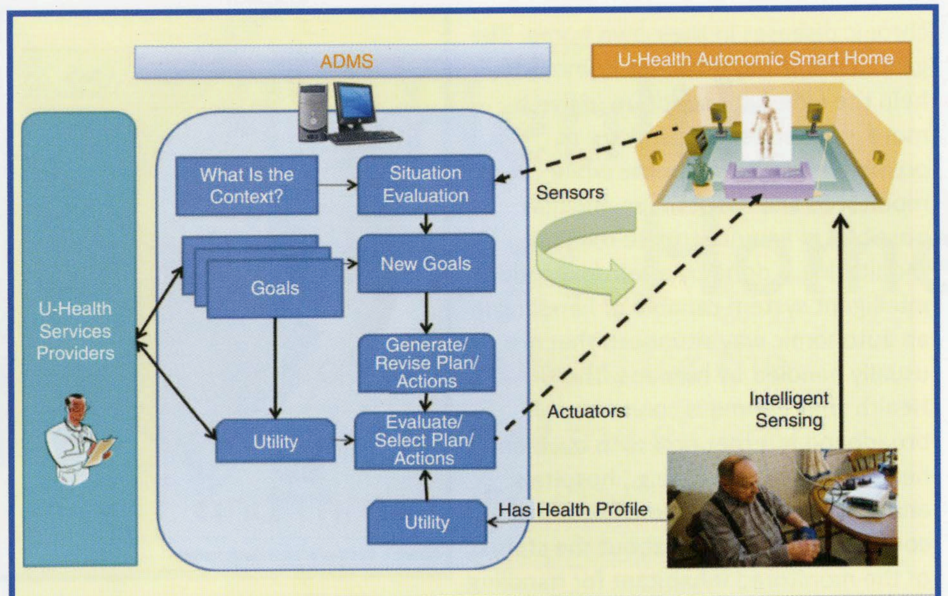


FIGURE 3 Autonomic decision-making system.

Autonomic Decision-Making System

The third layer is the autonomic computing part, the U-Health smart home ADMS, which is a computing system installed in the home and connected to the Internet (Figure 3). It constitutes the heart of the system where all the decisions are made. Data generated by the environmental sensors and medical sensors are transmitted to the ADMS smart home gateway through the HCN. The ADMS collects, filters, and analyzes the data and then saves it in a local database.

The goal of ADMS is to build a model of the inhabitant's environment and maintain their medical profile. All the received data is transformed into knowledge to feed the embedded decision system. Based on the generated knowledge and as a set of predefined policy rules, ADMS may be able to understand the situation of the inhabitant and make appropriate decisions about his/her safety and health care in an autonomic manner. These decisions can be either new knowledge in the system, actions to enforce in the smart home components (e.g., switching on a light and opening a window), or actions on the medical sensors (e.g., delivering a drug and changing the sampling frequency).

ADMS is also responsible for keeping the third party medical and safety institutions (e.g., hospital and police) fully appraised of the situation of the inhabitant.

Services

The last layer is the service part of the architecture. This layer describes the set of health-care and safety services that will be delivered by the ADMS. These services can be either related to safety in the daily life of the inhabitant or to their health. The portfolio of services that could be provided can depend on the specific status of the inhabitant and the available devices in the home. Depending on the particular diseases affecting the inhabitant, specific customized health-care services can be deployed by taking advantage of the available medical sensors and actuators in the market. At the same time, daily life support service can be deployed to ensure the safety and well-being of the inhabitant.

Role of Nanotechnology

Of the four layers mentioned earlier, autonomics, communications, networking, and related information technologies have been relatively well advanced in comparison with the sensors and actuators. In general, sensors to monitor the smart home environment are adequate, e.g., temperature, humidity, carbon monoxide, motion detection, and ambient lighting. Actuators to control switching devices on and off, opening/ closing window shades, and similar functions are also readily available. In the case of health monitoring, only a few devices are available, including blood pressure, pulse, heartbeat, and blood glucose. The anticipated sensor needs in a future smart home can be summarized as follows: 1) sensors or a lab-on-a-chip to monitor vital functions, including pH, cholesterol, complete blood count, white blood cell count, urine analysis, troponin-I (heart attack), bilirubin, and metabolic panel (Na, K, and Ca); 2) sensors for chronic diseases such as diabetes and asthma; 3) sensors for contagious diseases, e.g., flu, other viral diseases, and bacterial infections; and 4) sensors for specific diseases as demanded by the specific inhabitants of the smart home.

What is expected from a well-designed sensor system in any of the above cases? Small size and mass, low power consumption, minimal chemical resources, minimal human intervention or processing, reasonably rapid analysis, negligible false alarms, multiplexing capability for detecting multiple targets (i.e., performing multiple lab functions or detecting multiple viruses), reliability and robustness, and finally, a technology that is amenable to mass production to keep the cost low.

At POSTECH, we have chosen a silicon nanowire (Si-NW)-based bio-FET as our sensor platform (see Figure 4). A bio-FET is like a typical FET with the conventional gate replaced by an electrolyte solution (the sample and a reference electrode). The bio-FET has the ability to detect charges from biological molecules. At each stage of the process, the current–voltage characteristics of the bio-FET, including the so called threshold voltage, differ: 1) bare device, 2) after attaching the probe, and 3) after the probe-target hybridization. The Si-NWs in the bio-FET are about a 50-nm diameter, and conventional top– down fabrication is used for patterning, electrode definitions, and isolation. The Ag/AgCl reference electrode is fabricated on the wafer along with the channel/ reservoir for the sample. Currently, numerous devices are fabricated on a 6-in wafer with source–drain distances of several micrometers. Further, feature size reduction will allow an increase in the number of bio-FET devices per wafer. This fabrication also enables development of a biochip with multiple bio-FETs, each with a different probe for different purpose, thus allowing multiplexed operation.

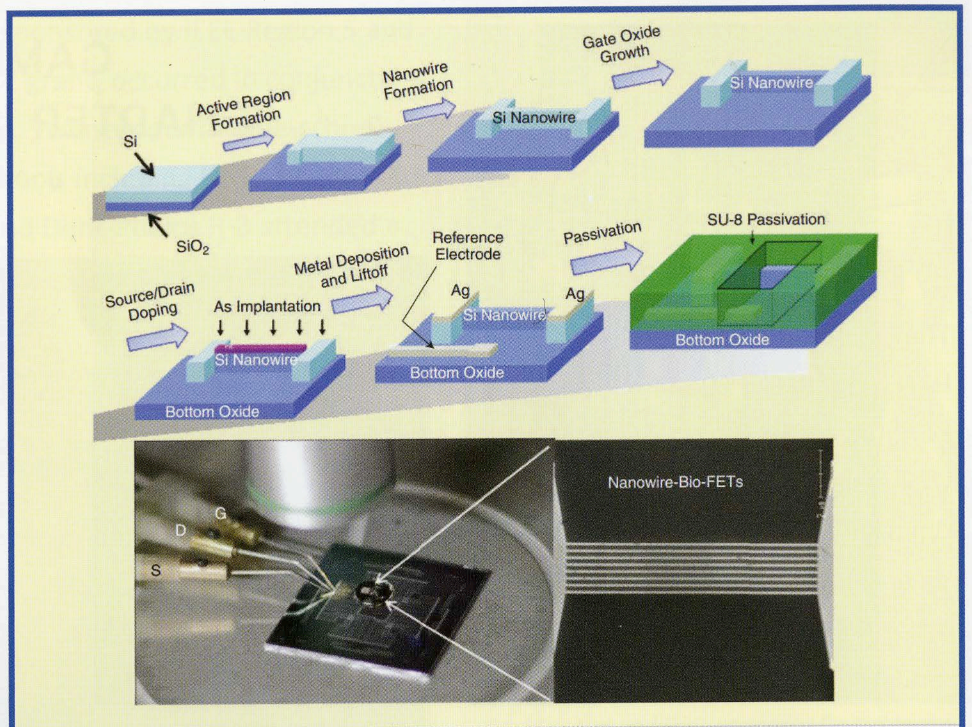


FIGURE 4 Silicon nanowire-based bio-FET.

Summary

The U-Health initiative is being pursued vigorously in several nations across the world with strong research and development programs in many universities with participation from hospitals and industry. The showstopper to realize the full potential of the initiative is the lack of availability of biomedical sensors that are small, reliable, sensitive, and inexpensive. This is a challenge that the NT community can take head-on since it has the materials, processes, tools, and the interdisciplinary knowledge to develop low cost biosensors.

Acknowledgments

This work was supported by the World Class University Program on IT-Convergence Engineering at POSTECH through the National Research Foundation of Korea funded by the Ministry of Education, Science, and Technology (R31-2008-000-10100-0).

Nazim Agoulmine[1], Jamal Deen[2], Jeong-Soo Lee and M. Meyyappan[3]
Division of IT Convergence Engineering, POSTECH, Pohang, Korea
1. University of Evry, France
2. McMaster University, Canada
3. NASA Ames Research Center, USA

GAMMA THETA CHAPTER INITIATION

By Dr. Steve E. Watkins

The Gamma Theta Chapter of IEEE-HKN held its Fall 2011 Initiation Banquet on 13 November at Missouri University of Science & Technology. Chapter President Kenneth Bassler, Vice-President Kathleen Venhaus, the other IEEE-HKN officers, and advisors inducted seven undergraduates, two graduate students, and two professional members.

Fall 2011 IEEE-HKN Initiates for the Gamma Theta Chapter (Missouri S&T)

The keynote presentation was given by new professional member, Dr. Sandra Magnus, on her experiences in the NASA shuttle program. Dr. Magnus presented the ECE Department and IEEE-HKN Chapter with an IEEE-HKN Medallion that she carried during 8-21 July 2011 on the final mission of the Space Shuttle *Atlantis*, STS-135. The medallion is now on display in the IEEE-HKN S&T display case.

IEEE-HKN Medallion Flown on the Shuttle by IEEE-HKN Member, Dr. Sandra Magnus.

Dr. Sandra Magnus, IEEE-HKN Member (Photograph courtesy of NASA)

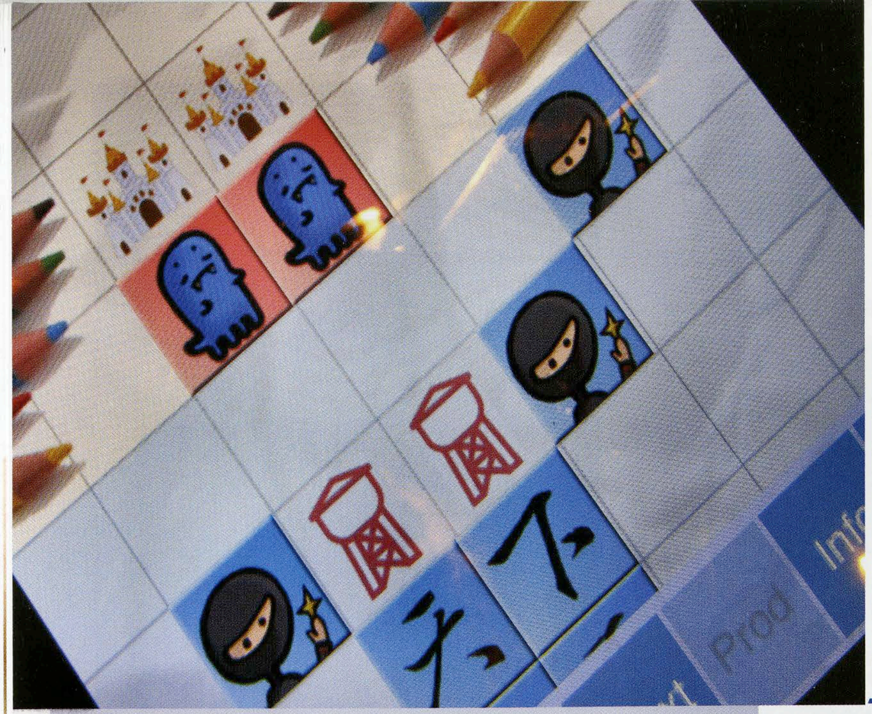
Dr. Sandra Magnus, a native of Belleville, IL, earned a bachelor's degree in physics from Missouri S&T in 1986 and a master's degree in electrical engineering from the campus in 1990. She earned a Ph.D. from Georgia Institute of Technology in 1996. Selected by NASA in 1996, she completed her first space flight in 2002 aboard the Atlantis. Her second flight took her to the International Space Station, where she lived for more than four months, between November 2008 and March 2009. Last July, she was a member of the Atlantis crew, which made the 135th and final mission of NASA's space shuttle program. She carried an IEEE-HKN medallion for the Gamma Theta Chapter of IEEE-HKN during this final shuttle mission and became an IEEE-HKN member in November 2011.

An associated pre-university event, sponsored by IEEE Region 5 and IEEE St. Louis Section through a PACE grant, occurred in conjunction with the IEEE-HKN initiation banquet. Twenty-four middle-school students and teachers from local schools including Rolla 31, St. Patrick School, St. James R-1, Salem R-80, and Dent-Phelps R-3 attended a pre-university reception and question session with Dr. Magnus. Afterwards, the pre-university participants attended the IEEE-HKN initiation banquet and met the college students and faculty. One of the teachers commented, "The pre-college event opened the eyes of my students about the possibilities available for their futures."

IEEE-Eta Kappa Nu Advisors are Drs. Steve E. Watkins, Sahra Sedigh, and Theresa Swift.

We would love to feature your IEEE-HKN Chapter in action! Email articles and pictures of your Chapter's activities, events, news or fundraisers to News and Copy Editor Alissa Rothstein at a.rothstein@ieee.org for possible inclusion in future issues of THE BRIDGE.

Dr. Magnus and Pre-university Participants. (Photograph courtesy of Avalon Photography)



Challenges and Opportunities in Mobile Game Development

By Simon S.H. LUI

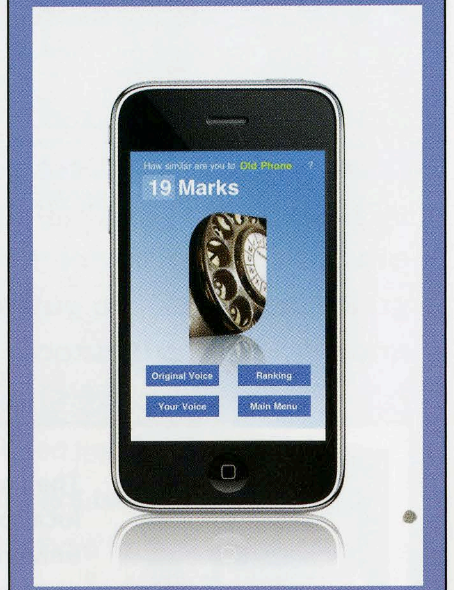
In the 1990s, most computer games were designed for family desktop computers. Nowadays, you will probably see people playing the games *Angry Birds* or *Where's My Water* on the bus with their iPhones or Android phones – and this shift has only been happening for a few short years. The world of gaming is changing tremendously. People are playing games on the go with smart-phones. For game developers, it is not as simple as "writing games for smaller consoles" – many challenges as well as opportunities are surfacing.

Challenges

Let's talk about challenges first. Mobile games need to run on devices with limited resources, including CPU, memory space, storage space, etc. In order to have a better understanding about these resources, imagine you are writing a proposal in your office. You are the CPU, performing thinking and writing tasks. With a higher CPU processing speed, you can finish a single task in shorter time. Your proposal booklet refers to the storage space, which is for saving data. Your work desk is the memory space. With a larger work desk, you have more space to process data and hence to finish your work more efficiently.

Resource Handling

Now for a real example. The latest iPhone 4S only has 0.5GB memory and a 2-core 0.8GHz CPU. A standard desktop computer usually has 4GB memory and 4-core 2.0GHz CPU. There is a huge difference between the two devices. However, the game *Street Fighter* is available on both the iPhone and the Windows computer platform. Users will fully expect similar graphics quality and performance on both versions. In this case, programmers have to handle resources very carefully – especially for the iPhone version. To deal with high-resolution graphics, the system needs to allocate memory space effectively. Programmers need to keep the memory as clean as possible. For example, only necessary graphic data are allocated with memory space. Once they are not needed, they will be released from memory immediately. In order to make the iPhone version with less computation power as responsive as the Windows computer version, programmers need to reduce the burden on the CPU. This can be achieved by using computational effective algorithms such as divide and conquer and the dynamic programming method for mathematical calculation.



Screenshot of the game SoundMitate. Player imitates a given sound and the program measures the accuracy of the user's imitation attempt.

The divide and conquer algorithm solves a problem by breaking it into sub-problems that are a smaller instance of the original problem, recursively solving these sub-problems, and combining these solutions to obtain the final answer. The dynamic programming method breaks down a complex problem into sub-problems where many of these sub-problems are the same. It solves all the sub-problems and reuses them to build up the final answer of the complex problem.

Lazy Loading

There is often a trade-off among computation time, memory space and accuracy. However, the bottleneck for mobile game design usually hinges on a lack of memory space. A popular programming technique called *lazy loading* is often used to solve the problem. This technique is very popular for mobile game designs but not commonly used on family computer games. The concept is to allocate memory resources at the very last moment when the system really needs it. In this case, memory will be clean for the longest possible time. However, without data preloading, the processing time may become slow.

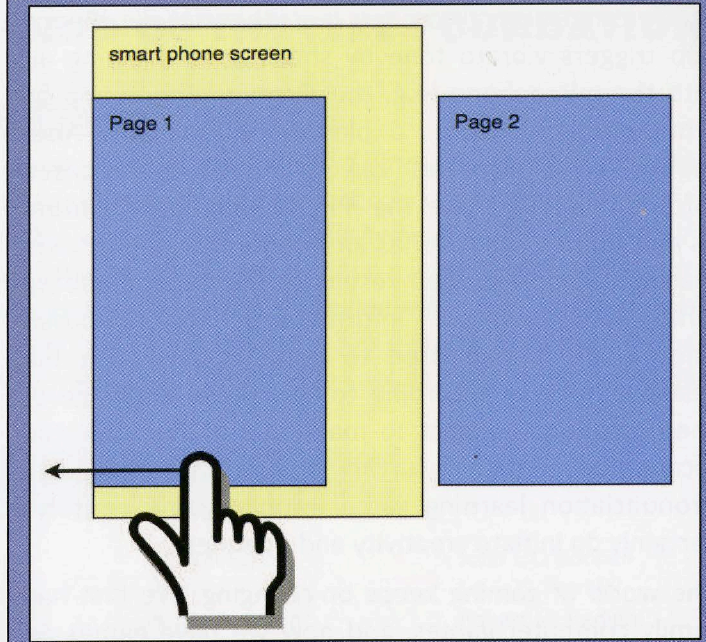
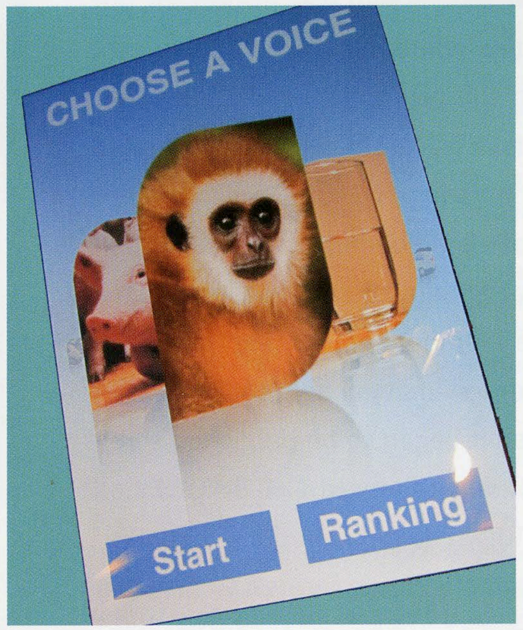


Figure 1. This example illustrates the concept of lazy loading (reading e-book). User is swapping page 1 out of the screen, and the system is going to load page 2. By lazy loading, the data of page 2 will not be loaded into memory until the last moment (when page 1 reaches the edge of the screen).

Another example of lazy loading is illustrated in Figure 1. Let's look at one more example of a trade-off decision. I developed an iPhone game called *SoundMitate* in which a player imitates a provided sound and the program measures how accurately the user can imitate the original sound. If I develop this game for the desktop platform, precision will be the most important consideration. However, speed is the greatest concern for mobile applications. I truncate 50% less salient frequency components when performing the audio comparison. In this case, it runs 10 times faster but yet preserves 98% accuracy, which is adequate for a game. Programmers should test their game thoroughly for making trade-off decisions. Usually programmers perform the test not only by themselves, but invite a focus group to try it out on a variety of platforms for more objective and diversified feedback.

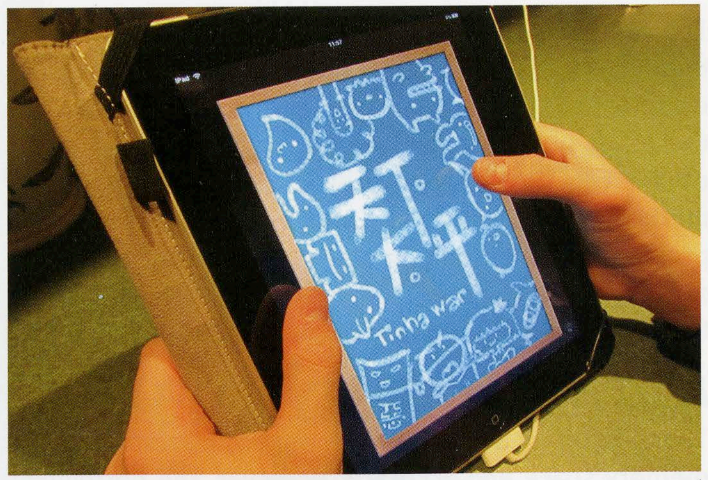


User Interface Design

For user interface design, all information on the screen needs to be concise because of the small screen size and low resolution. For example, a mobile game should have the least number of buttons available on the screen. The less important buttons should be discarded, or first hidden and triggered to appear by shaking the device or by a drag and drop function. The button cannot be too large or else it will occupy too much space, yet they can't be too small that they can't be tracked by human eye. If it is a touch-screen device, the button needs to be large enough such that it can be controlled by finger or stylus. For example, a 57x57 pixel button under the 72-dpi environment will do the job nicely on most smartphone using a touch screen.

Opportunities

On the other hand, mobile game consoles do have their own specialized features. For example, many mobile game consoles can be triggered by an accelerometer or gyroscope (e.g. the *ecViolin* iPhone app triggers vibrato tone by shaking), or blowing air into the microphone (e.g. the *Ocarina* iPhone app by Smule, which imitates a blowing instrument). Also, mobile game consoles can provide location-based information. Let's take the iPhone game *soundMitate* as an example again. It has an Internet ranking system. Players can upload their results to the cloud database with location-based information. Location-based information is also used to automatically tune the result of players according to the native language of their location. I expect to make use of the collected location-based data to further develop the system as a pronunciation learning game. Mobile game consoles certainly do initiate creativity and openness.



The world of gaming keeps on changing. We first had family computer games, and now we have games on mobile consoles. So what will be the next popular platform? Some contemporary games already go further and are designed for a daily life consoles such as on a table or a wall. In the changing world of gaming, challenges always come with opportunities, and it is good for developers and gamers to experience change!

About the Author: Dr. Simon S.H. LUI is an Assistant Professor of the Singapore University of Technology and Design (SUTD). He has 7 inventions on the iPhone/iPad platform, including #1 best selling apps in the Hong Kong, Taiwan, Malaysia, Indonesia and Canada iPhone/iPad app store.

IEEE-HKN HISTORY SPOTLIGHT

Eta Kappa Nu (HKN) is the result of the vision of Maurice L. Carr, an electrical engineering student at the University of Illinois. He shared that vision with nine other students who together founded the organization on 28 October 1904. The original perspective regarding qualifications for membership was that scholarship was important but that the selection of students with the character and attitude that would make them probable leaders in the profession was even more important. Eta Kappa Nu's first publication was a small four-page leaflet titled "The Electrical Field," issued in the spring of 1906. It was devoted almost entirely to the subject of employment. It contained commentary about four companies that employed electrical engineers, and it included the list of names of the members graduating from both the University of Illinois and the Purdue University chapters. This leaflet was published annually until 1909, when it began to be published semi-annually. In 1913, "The Electrical Field" was renamed THE BRIDGE and was published annually. Today, THE BRIDGE is published twice a year, and beginning in 2011 was available in an electronic format.

Maurice L. Carr
(Image courtesy of the University of Illinois Archives, Alumni and Faculty Biographical File, Record Series 26/4/1)

IEEE-ETA KAPPA NU RESTRICTED FUND OF THE IEEE FOUNDATION

2011 Annual Fund Contributors

IEEE-Eta Kappa Nu gratefully recognizes the generosity and support of its members and other friends listed here. Their support enables IEEE-HKN to continue to serve students and professionals alike by hosting leadership conferences and networking opportunities for career advancements. IEEE-HKN awards provide distinguished recognition to outstanding individuals who have contributed significantly to the advancement of the profession and had a wide reaching and positive impact on humanity. THE BRIDGE magazine, new features on the IEEE-HKN website (www.hkn.org), and networking groups such as LinkedIn, are enjoyed by members around the world. IEEE-HKN remains a premier honor society, and thanks those willing to donate their time, talents, and resources to continue this important mission.

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Lambda Iota – Hong Kong

On Friday, 13 January 2012, IEEE-Eta Kappa Nu (IEEE-HKN) established its first chapter outside the U.S.. IEEE-HKN President Dr. Stephen M. Goodnick, presided over the installation of the IEEE-HKN Lambda Iota Chapter at The University of Hong Kong's event. A total of nineteen students, faculty and professionals were inducted at the ceremony. Prof. Paul Y. S. Cheung, 2012 director of the IEEE Foundation, former IEEE Region 10 director, and appointed IEEE-HKN Faculty Advisor for IEEE-HKN Lambda Iota Chapter, along with Prof. Victor O. K. Li, Head and Chair of the Department of Electrical & Electronic Engineering at the University, both of whom were previously inducted as IEEE-HKN members (Eta – Board of Directors and Beta Theta, respectively), assisted with the installation and induction activities. Notable IEEE members present at the new chapter installation and induction were the 2012 IEEE Board of Directors, including IEEE President and CEO Gordon Day, 2012 IEEE President-Elect Peter Staecker, 2011 IEEE President Moshe Kam, and 2006 IEEE President Michael Lightner.

Lambda Eta – India

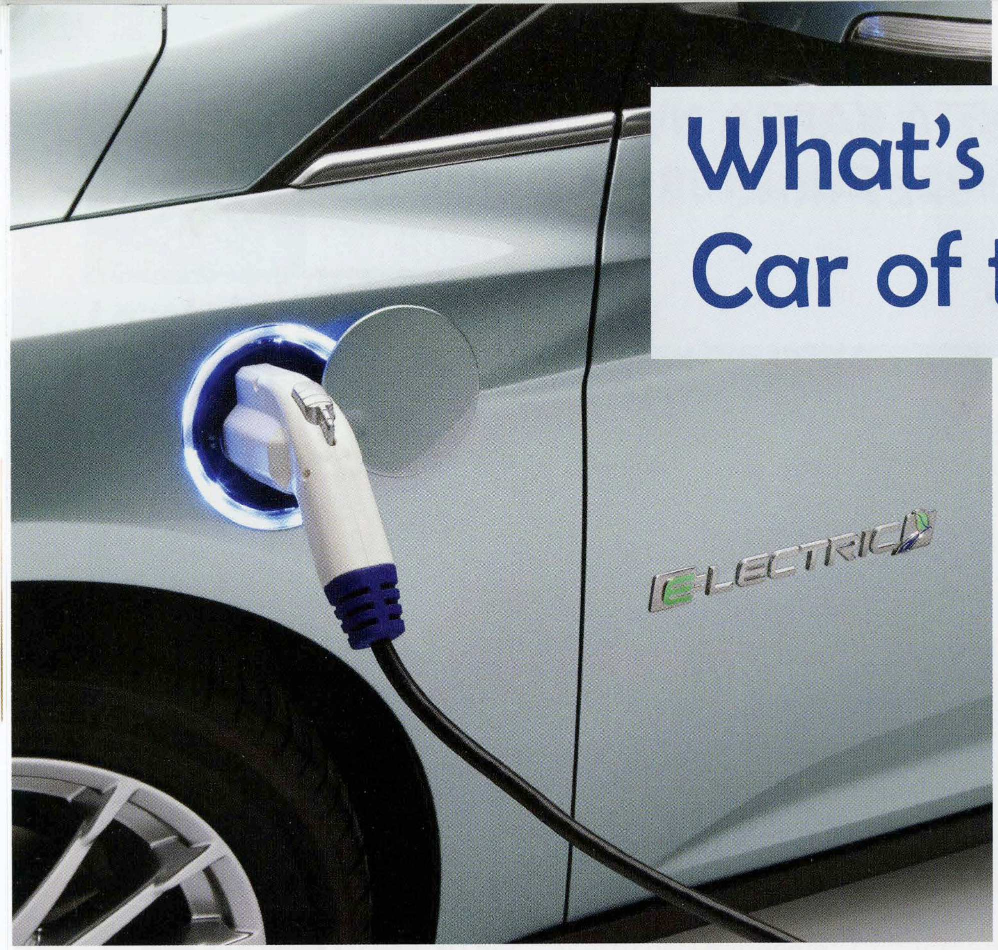
On Friday, 10 February 2012, IEEE-Eta Kappa Nu (IEEE-HKN) installed its second chapter outside the U.S.

IEEE-HKN President Dr. Stephen M. Goodnick, presided over the installation of the IEEE-HKN Lambda Eta Chapter at The Bharati Vidyapeeth's College of Engineering. A total of eighteen students, faculty and professionals were inducted at the ceremony. Prof. Rahul Bahl, appointed as the IEEE-HKN Faculty Advisor for IEEE-HKN Lambda Eta Chapter, assisted with the installation and induction activities and the College Principal, Dr. K. C. Tiwari, was also on hand. Almost 200 individuals attended the installation and induction.

IEEE-ETA KAPPA NU ESTABLISHES FIRST CHAPTERS OUTSIDE U.S.

Lambda Theta – Canada

On Monday, 5 March 2012, IEEE-Eta Kappa Nu (IEEE-HKN) installed its third chapter outside the U.S. IEEE-HKN President Dr. Stephen M. Goodnick, presided over the installation of the IEEE-HKN Lambda Theta Chapter at Dalhousie University. A total of seventeen students, faculty and professionals were inducted at the ceremony. Dr. Mo El-Hawary, appointed as the IEEE-HKN Faculty Advisor for IEEE-HKN Lambda Theta Chapter, assisted with the installation and induction activities. Dr. Josh Leon, Dean of Engineering, Dr. Zhizhang (David) Chen, Head of the Electrical and Computer Engineering Department, and Dr. Ferial El-Hawary, past director of Region 7 and past President, IEEE Canada, were also in attendance.



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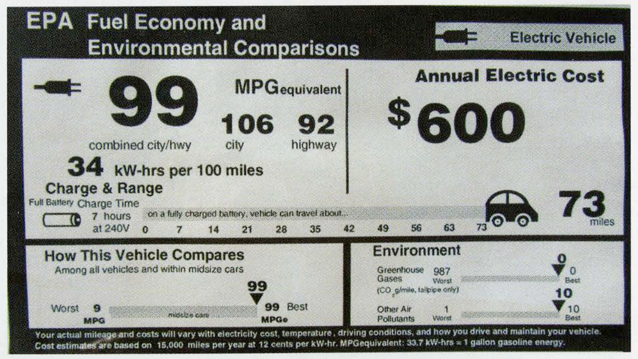
What's Driving the Car of the Future?

By Randy Reisinger and Ali Emadi

McMaster Institute for Automotive Research and Technology (MacAUTO)
McMaster University, Canada

The automobile has become the default method of transportation for hundreds of millions of people in developed countries. Travel in the automobile is available with unparalleled levels of comfort, convenience and often conveys a sense of social status on its owner, but it is becoming increasingly apparent that these attributes come at a very high price, economically, ecologically and politically. In the first century of the automobile's existence, it has consumed much of the worlds oil supply. With nearly one billion vehicles on the road globally -- a number that is increasing with the economic growth of large population areas like China and India -- the automobile may soon consume more petroleum than our planet's oil companies can sustain cost-effectively for consumers. These increases in demand are straining the price of fuel and challenging auto manufacturers to market a commercially viable automobile. While the automobile's historical success was mostly based upon readily available and inexpensive fuel, its future success will depend in large part on minimizing its use of fossil fuel to justify a new vehicle purchase.

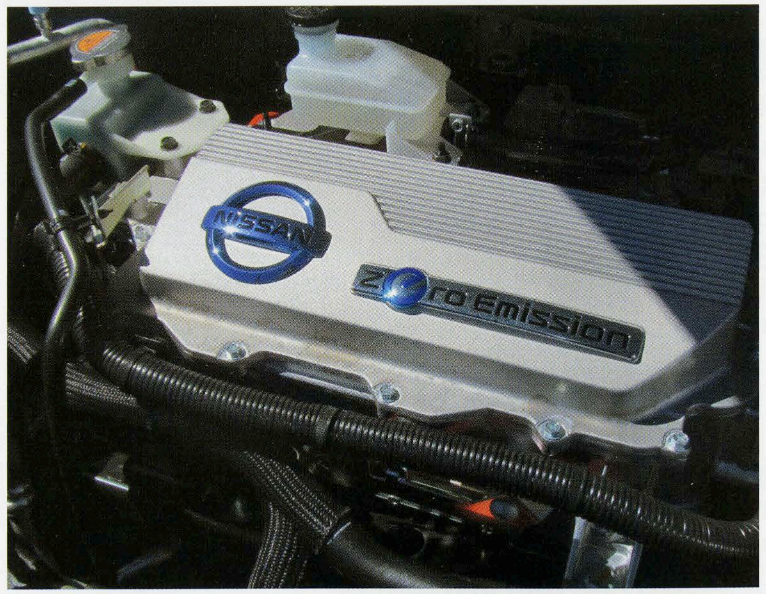
Lower Emissions and Improved Fuel Efficiency



Increasingly, governments around the world are becoming concerned about the amount of carbon and other greenhouse gas emissions that are produced by so many automobiles, and are introducing increasingly stringent legislation to limit the emissions they produce. The auto industry is feeling additional pressure in the form of increased fuel efficiency standards requiring automakers to produce more fuel-efficient vehicles.

The average vehicle driven in North America is roughly 10% to 18% percent efficient on average at converting the energy in gasoline into forward motion. Often the driver is the only "payload" in the vehicle. The typical driver's weight is roughly 5% of the weight of the vehicle. Therefore, 95% of the energy used in personal transportation is used to get the vehicle to its destination and only 5% to deliver the driver. Combining these two factors yields the efficiency of moving the driver to its destination. It's less than 1% for the majority of personal transportation.

For most of the past century, fuel efficiency has been a lower priority than reliability or performance, for example, but recent events discussed above have begun to elevate the priority for improved fuel efficiency among auto designers and manufacturers.

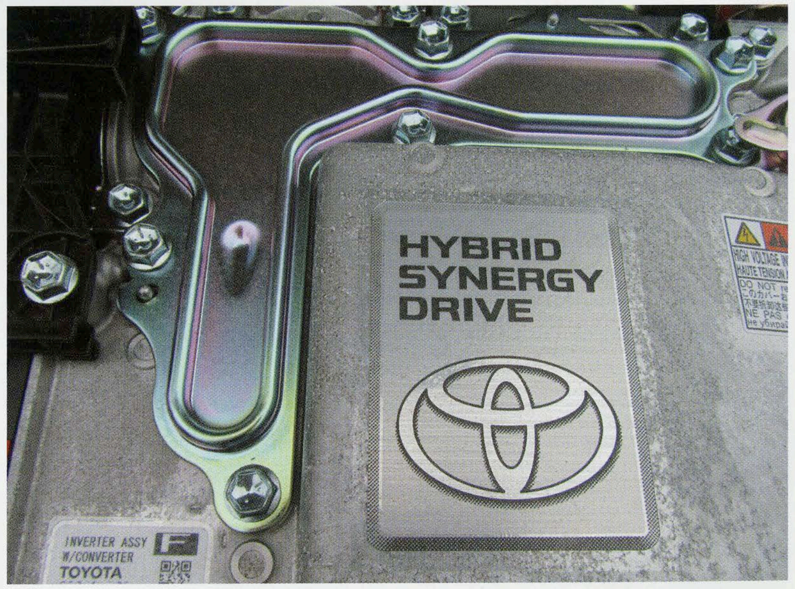


New Approaches and New Technologies

New or improved technologies are also playing a role in reducing fuel consumption. For instance, improvements in engine technology and six, seven or even eight speed transmissions are improving traditional designs. Improvements in battery technologies have enabled consideration of new hybrid electric and plug-in hybrid electric powertrain designs which off-load some of the vehicle propulsion to electric motors which are inherently much more efficient (peak efficiency of up to 98%). While the concept sounds simple, designing and building these powertrains requires an understanding of electro-mechanical energy conversion and power electronics -- a craft that was all but lost during the digital electronics explosion of recent decades. As a result, critical engineering talent is in short supply and powertrain designers must now consider electronic components as well as mechanical components to develop next generation efficient vehicles. Powertrain engineers that fully understand both disciplines are rare, yet circumstances point to this direction as critical to the journey toward greater energy efficiency in personal and mass transportation.

That journey begins with hybrid electric vehicles that, as previously mentioned, substitute some electric motor propulsion, for work traditionally dedicated to the internal combustion engine (ICE). While these designs are generally more efficient than their ICE counterpart, all of the electricity used for propulsion is still generated by the ICE (except the electricity from regenerative braking). Gains in efficiency come from the way in which the energy is used and recovered during regenerative braking. When hybrid designs were first introduced, they typically doubled the fuel economy of the average ICE vehicle. Since that time, as pressure for fuel economy has mounted, ICE designs and control have also improved. Current hybrid designs, while significantly more efficient than conventional ICE vehicles, have led the way to even more efficient plug-in hybrid electric designs.

This, more aggressive approach to fuel efficiency, off-loads still more of the inefficient ICE's work, by utilizing some energy from an external source (such as the electric power grid) to increase the percentage of efficient electric propulsion per trip, with the ability to charge from the grid between trips. In this design, liquid fuel consumption depends upon the length of a trip, but is minimized by using electric power exclusively or in blended fashion for the first portion of the trip. For example, if a plug-in hybrid electric vehicle has an all-electric range of 10 miles, and the trip length is 20 miles, liquid fuel will be used for only half the trip. The result is a vehicle where a significant portion of its motive force is supplied by efficient electric propulsion and liquid fuel consumption is minimized.



If this discussion seems to be ignoring the electricity consumed, it's for two good reasons. First, the electricity required to move the vehicle, while not insignificant, is less and has a much lower cost and greatly reduced emissions as compared to a conventional vehicle. For instance, a Toyota Prius consumes roughly 300 watt-hours per mile of total energy. With an average 1,000 miles per month, and a $0.12 cost per kWh, a fully electric version of Prius would consume roughly $36.00 worth of electricity per month. While this is a hypothetical example, it points out the magnitude of cost savings that can be achieved by electrifying even traditional vehicles.

Second, traditional measures of energy consumed such as miles per gallon or litters per hundred kilometers are well known to those who are interested in such measures, but fall short of describing energy usage for blended liquid fuel and electricity. Perhaps a more accurate metric is Watt-hours per mile or Watt-hours per kilometer. This metric can be used to measure the combined energy used for the trip. While it better describes the energy used, it is likely to be some time before this notion becomes popularly recognized.

Image © Copyright Toyota Motor Corporation

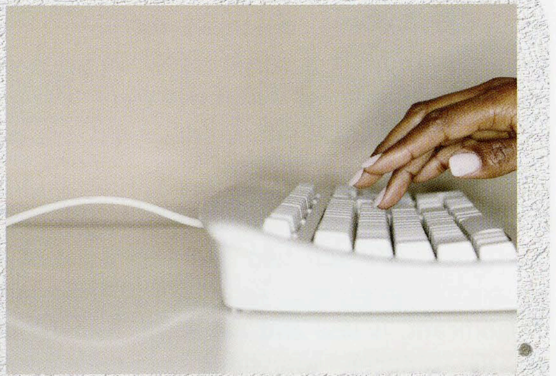
Summary

Trends in automotive powertrain design are becoming clear. The journey to more efficient and cleaner transportation began with the success of hybrid electric vehicles like the pioneering Prius from Toyota. The hybrid market has been steadily growing. Plug-in hybrid electric vehicles are starting to appear in the market, led by the Chevrolet Volt and, more recently the plug-in Prius. These and similar designs are leading the way to future all-purpose vehicles. For now pure electric vehicles, like the Nisan Leaf, with limitations on range, will best be used as commuter vehicles, but looking a few years further into the future, advances in power electronics, electric propulsion motors, battery capacity, and new methods of charging will bring the all-electric vehicle into the mainstream. Until then, look for hybrid electric vehicles and plug-in hybrid electric vehicles for clean air and affordable transportation.

Image © Copyright General Motors

About the Authors: Randy Reisinger is the Research Program Development Manager at the McMaster Institute for Automotive Research and Technology (MacAUTO), McMaster University. Ali Emadi, Ph.D. is the Canada Excellence Research Chair in Hybrid Powertrain and Director of MacAUTO at McMaster University.

Applications Being Accepted for the IEEE PES Scholarship Plus Initiative™



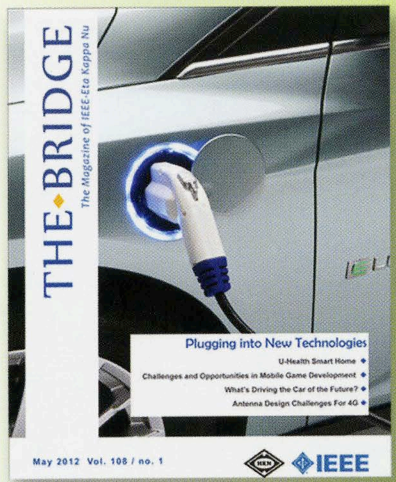
Applications are being accepted for the 2012-2013 Academic Year for the PES Scholarship Plus Initiative™. The goal of the initiative is simple: increase the number of well-qualified, entry-level engineers in the power and energy industry. Under this program, recipients can graduate with recognition as being a PES Scholar, receive up to $7,000 in scholarship funds and gain industrial experience through internships/co-ops. The application deadline is 30 June 2012. Additionally for the first time, the top PES Scholar from each IEEE Region will be selected as the IEEE PES John W. Estey Outstanding Scholar. These 6 individuals will receive (a) $5,000 for school expenses (tuition, books, student fees, etc.) (b) IEEE and IEEE PES Student Membership for twelve months and (c) a travel honorarium up to $1,000 to attend the IEEE 2013 PES General Meeting. To be eligible, an individual must be a U.S. citizen or permanent resident, currently enrolled full-time in an engineering program at a university/college or community college with a GPA of 3.0 or higher on a 4.0 scale (or equivalent). The higher education institution must have an ABET-accredited, 4-year electrical engineering program and offer undergraduate courses in power engineering. Engineering students early in their college careers are encouraged to apply, even if in June 2012 they have not yet declared electrical engineering as their major. In Fall 2012, the individual must be enrolled in an electrical engineering program working toward a bachelor's degree. To apply, or to learn more about the eligibility, selection and renewal criteria, visit www.ee-scholarship.org.

Call for Editor-in-Chief and Editorial Board Members

IEEE-HKN is seeking volunteers for the positions of Editor-in-Chief and Editorial Board Members of THE BRIDGE

Major Responsibilities - Editor-in-Chief

- Supporting the vision and direction of THE BRIDGE
- Managing the peer review process
- Soliciting manuscript submissions
- Deciding which manuscripts to publish



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- Soliciting manuscript submissions
- Collaborating on the selection and review of manuscripts

Application Procedure:

The application should include a letter of interest and a CV

Submit your application to Alissa Rothstein, IEEE-HKN Program Manager at info@hkn.org no later than 1 July 2012

Jacquelyn K. Nagel

Jacquelyn K. Nagel is currently an Assistant Professor of the School of Engineering at James Madison University (JMU). Prior to JMU she worked as engineering contractor at Mission Critical Technologies working on the DARPA funded Meta-II Project.

Jacquelyn has gained seven years of diversified engineering design experience, both in academia and industry, that spans a range of contexts, including: model-based design, new product design, bio-inspired design, electrical and control system design, manufacturing system design and design for the factory floor.

She has worked at Kimberly-Clark, Motoman, and Intel and gained cooperative education experience in the areas of industrial automation and manufacturing. During her doctoral work she designed bio-inspired sensors that perform "up front" processing which vastly reduces data streams and increases efficiency, as well as developed computational design tools and methods to make biological inspiration accessible to engineering design problems.

During her master's work she developed a method for the design, integration and control of modular rapid manufacturing systems. Her current research efforts are focused upon modeling and analysis of bio-inspired sensors and investigation of how biological inspiration can influence complex system design. Jacquelyn obtained her Ph.D. in Mechanical Engineering from Oregon State University researching bio-inspired design with application to sensor design. She earned her M.S. and B.S. in Manufacturing Engineering and Electrical Engineering, respectively, from Missouri University of Science & Technology (formerly University of Missouri-Rolla).

Why did you choose to study the engineering field?

I love to solve puzzles, and I have a strong curiosity to figure things out or how something works. When I was told that engineers solve problems, I knew it was the right career for me and never looked back.

What do you love about engineering?

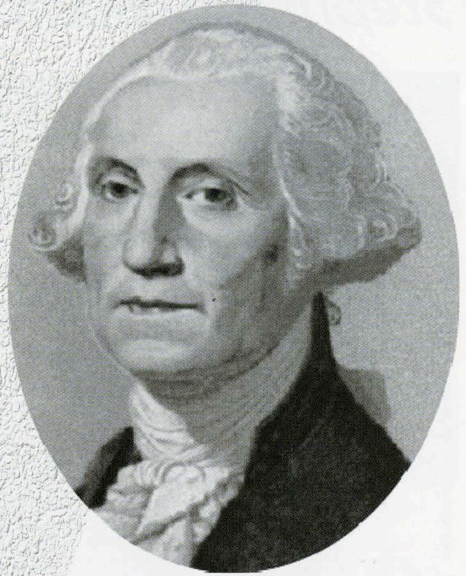
That engineering impacts society in so many ways. Engineers improve quality of life and keep us, as a people, moving forward.

What don't you like about engineering?

The inaccurate stereotypes about engineering. Students that are good in math and science are often told "You would make a good engineer." There is so much more to engineering than solving math and science problems! Such as applying those math and science concepts to obtain one of many possible solutions, designing a product, making trade-offs, interacting with clients, working on teams, building prototypes, and developing an intuition for problem solving. Yes, a good foundation in math and science is needed as well as a penchant for those subjects, but many other characteristics and skills are needed.

Characteristics and skills that are of equal importance are creativity, tenacity, understanding the "Big Picture" as well as the details, the ability to make connections among the sub-disciplines of engineering and potentially other domains, problem solving skills, communication skills, and project management skills.

Whom do you admire?



I admire all the pioneering women in the science, technology, engineering, and mathematics fields because they demonstrate dedication and passion! These women do not let society dictate what they do, rather they blaze their own trails and serve as role models. I admire George Washington because he was a great leader and had a genuine concern for the people of his country. He accepted the challenge to become the first U.S. president, an unknown role. He also was not afraid to "get his hands dirty" with low-level tasks. I admire Jack Kilby because of his ability to pull from different disciplines when solving a problem. He designed a solution to circuit manufacturing, which resulted in the first integrated circuit, that combined electrical engineering, manufacturing and design.

How has the engineering field changed since you started?

Two changes come to mind: 1) the increased number of pre-university programs to introduce engineering to young people; and 2) the increased diversity of engineering professionals in ethnicity, age, perspective, and motivation.

What direction do you think that the engineering field is headed in the next 10 years?

The problems engineers will be faced with in 10 years will be more complex, and require a multidisciplinary skill set. To meet that need, I think engineering education will become broader, but integrated, to create the engineer that can handle complex, multidisciplinary problems.

What is the most important thing you have learned in the field?

Engineering work is rarely confined to a specific discipline. Having an open mind and willingness to learn new things or perform tasks outside your specific training (i.e., electrical engineering) will greatly help you in your career and build respect amongst your colleagues.

What advice would you give to recent graduates entering the field?

Learn from your mistakes. Do not be afraid to ask for help and learn from your colleagues - no one has all the answers. Take on tasks outside of your comfort zone or expertise area - they will broaden your perspective and experience, which will make you a more versatile and effective problem solver.

If you were not in the engineering field, what would you be doing?

I entertained being an artist or a chef, which appeals to my creative side. But my practical and methodical side, which is dominate, would have probably taken me into physics as I have a strong curiosity about our world. As I began researching biology for my doctoral work, I realized how much I like learning biology and about how things in nature work. I would put biologist at the top of the list.

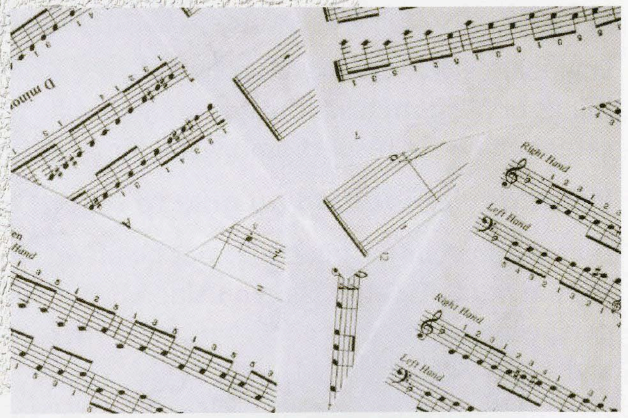
Finish this sentence: "If I had more time, I would...

...take kickboxing and aerobics classes regularly."

Stephen Goodnick

Stephen Goodnick is the IEEE-HKN Board of Governors President. He currently holds the position of Associate Vice President, Research at Arizona State University. Prior to this position, he was Interim Deputy Dean and Director of Nanotechnology for the Ira A. Fulton School of Engineering. He came to ASU in Fall 1996 as Department Chair from Oregon State University where he was a professor of electrical and computer engineering. He has also been a visiting scientist at the Solar Energy Research Institute and Sandia National Laboratories and a visiting faculty member at the Walter Schottky Institute, Munich, Germany; the University of Modena, Italy; the University of Notre Dame; and Osaka University, Japan. Dr. Goodnick served as President (2003-2004) of the Electrical and Computer Engineering Department Heads Association (ECEDHA), and as Program Chair of the Fourth IEEE Conference on Nanotechnology. He has published more His honors and distinctions include: Fellow, IEEE (2004), Alexander von Humboldt Research Fellow, Germany, 1986; College of Engineering Research Award, Oregon State University, 1996; Colorado State University College of Engineering Achievement in Academia Award, 1998; IEEE Phoenix Section Society Award for Outstanding Service, 2002.

Why did you choose to study the engineering field?



When I went in high school, we really had no idea what being an engineer meant, and what the career opportunities were. The situation today is only slightly better, students still study mathematics and the sciences, but have little exposure to the application to engineering design and problem solving. In high school, I liked physics and mathematics as well as music, and was considering entering one of these majors in college, but my parents strongly suggested I go into engineering as a practical career choice, and thankfully I listened to them.

What do you love about engineering?

What I really love about engineering is the opportunity it provides for working on technology and solving problems that have an impact in addressing real world problems. I feel very fortunate to have a career that allows me to work on interesting problems which at the same time may provide benefits to society as a whole.

What don't you like about engineering?

Engineering has traditionally been too narrow in terms of attracting a broad range of individuals to the profession representing society as a whole, which is partly historical, and partly perceptual. We have to do a better job of making engineering an attractive and inclusive profession in order to attract the necessary talent to our field.

Whom do you admire?

John Bardeen, Andy Grove, Steve Jobs

How has the engineering field changed since you started?

The most consequential change in engineering over my career has been the revolution in computing and communications. When I started graduate school, desktop computers were just beginning to appear and were incredibly crude by today's standards, and there was no internet or world wide web. These major transformations in technology have literally revolutionized engineering at all levels in terms of instantaneous access to information, computer aided design, how and when engineers work.

What direction do you think that the engineering field is headed in the next 10 years?

We have just experienced the largest growth in information technology in human history, which is now starting to permeate all fields of engineering. In particular, biomedicine and biosciences are rapidly advancing due to information technology and to advances in nanotechnology, and I expect to see major developments in genomics based diagnostics and therapeutics for treating some of the major diseases affecting humankind. In terms of information technology itself, we are rapidly reaching the limits of size scaling in terms of microprocessor based computing, even with advances in nanotechnology over the next decade. I expect that the focus will shift from increasing raw computing power to applying this power to increasingly parallel systems for information processing, ultimately mimicking --- with experts in those fields, and being able to form collaborative teams with people from diverse disciplines.

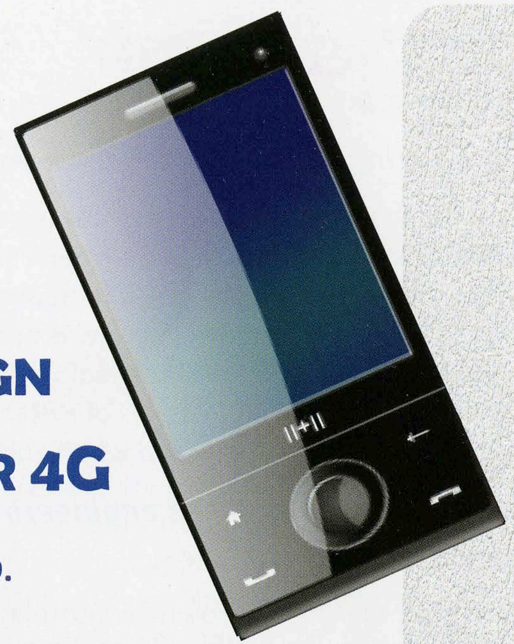
If you were not in the engineering field, what would you be doing?

I probably would have gone into one of the basic sciences like physics, although there is no linear career path. What I thought I would be doing when I started school and what I ended up doing are completely different, due to a number of opportunities that appeared unexpectedly at various stages of my career.

Finish this sentence: "If I had more time, I would...

...study jazz piano, learn Japanese, study cosmology, and take an extended wilderness trek."

ANTENNA DESIGN CHALLENGES FOR 4G



By Frank M. Caimi, PH.D.

The trend in mobile wireless devices has been to provide faster access, improved processors, more memory, brighter and higher resolution screens, additional connectivity with Wi-Fi, GPS, third generation (3G), and fourth generation (4G) world access — all with longer battery life in thinner, sleeker packages. Compound this with the desire of mobile operators to expand their available band allocations, and what results is a difficult industrial design arena, where suppliers are vying for physical space within the confines of a smartphone or similar device to accommodate necessary components. One such component is the antenna — essentially a transducer that converts time varying electrical current to radiated energy, and often considered a last minute addition to the physical structure. Now with the introduction of 4G and 1 × 2 or 2 × 2 multiple-input multiple-output (MIMO) communications protocols, not one but two antennas are needed, each with specific requirements typical of any transducer: bandwidth, efficiency, mutual coupling, size, and cost. With newer Third Generation Partnership Project (3GPP) definitions for carrier aggregation, simultaneous band coverage will be also be necessary. These trends introduce significant challenges for effective antenna design.

ANTENNA PHYSICAL DESIGN CONSTRAINTS

A number of factors affect MIMO antenna performance in a handheld mobile communication device. While these factors are related, they generally fall into one of three categories: antenna size, mutual coupling between multiple antennas, and device usage models.

Antenna Size: The size of an antenna is dependent on three criteria: bandwidth of operation, frequency of operation, and required radiation efficiency. Bandwidth requirements have obviously increased, now covering a frequency range from 698 to 2700 MHz. A simple relationship exists between the bandwidth, size, and radiation efficiency for the fundamental or lowest frequency resonance of a physically small antenna. Generally stated, fractional bandwidth is proportional to the physical volume (containing the majority of the antenna currents) multiplied by the inverse of the radiation efficiency. Therefore, antenna designers have at their command a design space where bandwidth, antenna size, and efficiency can be traded. Since radio frequency (RF) currents exist not only on the antenna element but also on the attached conductive structure or counterpoise, the actual antenna is much larger that it visibly appears, and therefore the bandwidth is also larger. Electromagnetic modal analysis of a typical smartphone indicates that the fundamental mode is just above 1 GHz; thus, performance

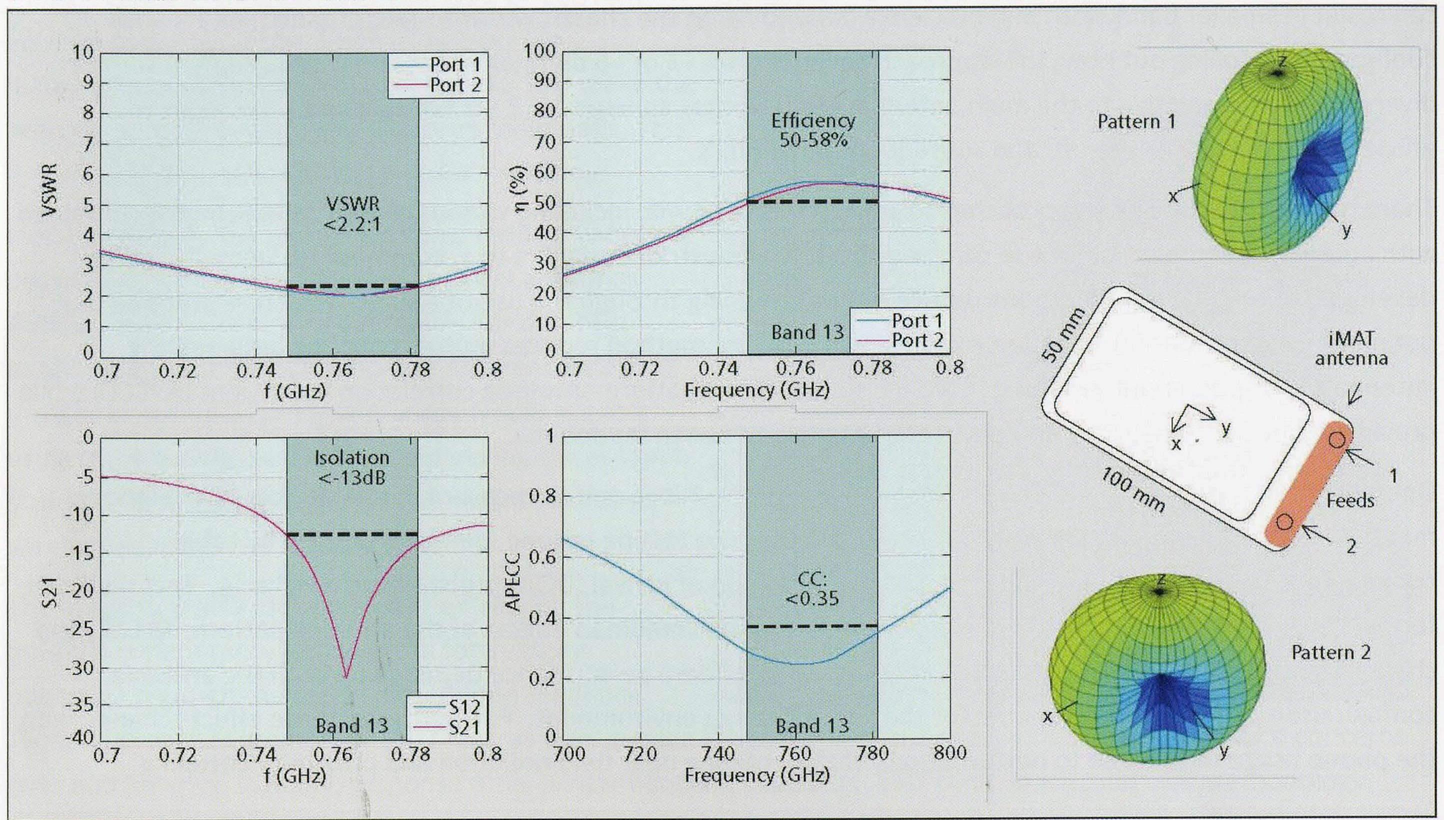


Figure 1: Coupling and radiation patterns resulting for antennas at one end of the phone chassis using isolated mode antenna technology (IMAT) — mutual coupling null results in higher efficiency and rotated antenna patterns, leading to reduced APECC.

bandwidth progressively decreases at lower excitation frequencies. Covering 698–960 MHz (bands 12, 13, 17, 18, 19, 20, 5, and 8) with a completely passive antenna becomes difficult without making sacrifices in radiation efficiency or size. In most cases, the requirements imposed by operators suggest minimum radiation efficiencies of 40–50 percent, so that meeting a minimum TRP requirement essentially requires trade-offs between the power amplifier (PA) output and the achievable antenna efficiency. In turn, poor efficiency at the antenna translates to less battery life, as the PA must compensate for the loss.

Mutual Coupling Limitations: Since the longitudinal dimension of the chassis is a primary contributor to the fundamental chassis resonance mode, an antenna located at either end on top of the phone will excite nearly the same current modal distribution, and therefore produce virtually the same radiation pattern. Since both antennas are coupled to the same mode, they experience mutual coupling so that power introduced into one antenna is partially coupled to the opposite antenna's source resistance, and is subsequently lost. A common solution is to relocate one antenna to excite a different radiation mode on the chassis, which

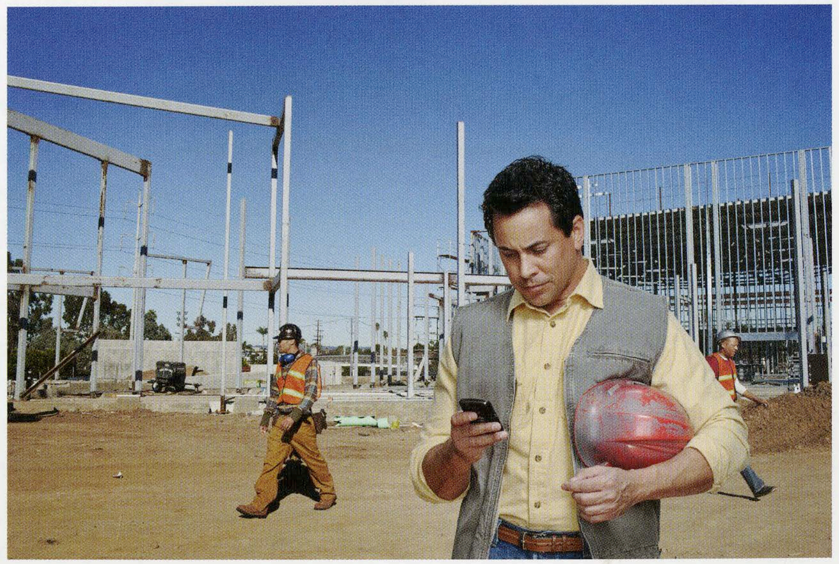


Image Courtesy of Verizon Wireless

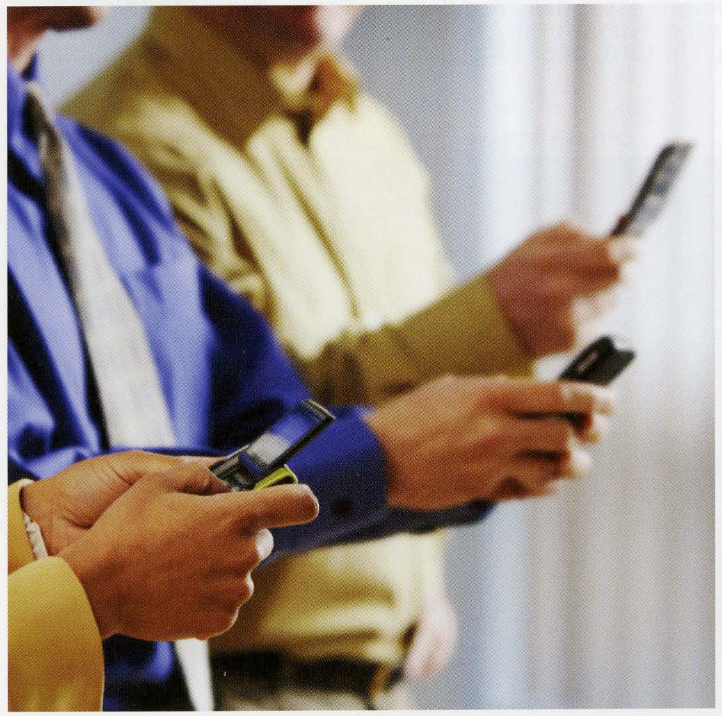
can result in smaller bandwidth and efficiency depending on the chassis width-to-length ratio. For 1 × 2 MIMO configurations rolling out now, this approach can meet the –3 or –6 dB relative efficiency requirement for the diversity antenna relative to the main antenna, but becomes an issue for 2 × 2 MIMO due to the reduced efficiency/bandwidth trade-off, and subsequent power loss.

There have been numerous approaches to solving this dilemma, including various chassis modifications combined with antenna placement, but these can be difficult for industrial designers to accommodate. Several recently developed antenna design methods reduce mutual coupling through the use of a single-structure antenna that optimally excites different radiation modes (Figure 1). The method reduces mutual coupling between the antenna's two feedpoints, resulting in a minimum antenna pattern envelope correlation coefficient (APECC) while providing improved efficiency and equal gain balance between feedpoints.

Operator requirements for APECC can also be difficult to achieve and to measure in real devices. Correlation measurements can vary significantly depending on how the testing is done, being influenced by cable connections, device positioning, and the channel direction of arrival (DOA) probabilistic weighting. Test methods for determining the overall MIMO performance due to the combined effects of the antenna pattern, APECC, and channel model are current topics in 3GPP, since MIMO system performance depends on both the antenna configuration and the channel model for the specific usage environment. Furthermore, these effects change with the phone usage model due to perturbations of the antenna near field radiation and proximity detuning.

Current Solutions

Obvious solutions would be to increase the antenna system size (i.e., the antenna and phone chassis footprint) and/or reduce the radiation efficiency. Since 4G smartphones require at least two antennas, neither approach is necessarily practical from a design standpoint. Some solutions also involve splitting the system architecture into low band and high band sections, and using separate antennas for each section, thereby doubling the number of antennas.



Plausible solutions motivated by industry are the following:

- Limit the antenna(s) instantaneous bandwidth within current antenna space allocations to allow use of two antennas without compromising the industrial design (antenna supplier motivation)
- Make the antenna(s) smaller to achieve a compact and sleek device with greater functionality by limiting the instantaneous bandwidth with same or improved antenna efficiency (original equipment manufacturer [OEM] motivation)
- Improve the antenna efficiency and therefore the network performance by controlling the antenna instantaneous frequency/ tuning (operator motivation)
- Make the antenna agile to adapt to different usage models (OEM/user/operator motivation)
- Combinations of the above

Perhaps the simplest approach is to limit the instantaneous operation to a single band and make the antenna frequency agile on a band-by-band basis. This is the most basic type of "state-tuned" antenna.

Not surprisingly, the industry is considering a variety of possibilities to provide adaptive or smart antennas. Adding requirements for adaptability for different usage models, or to accommodate different industrial designs or manufacturing tolerances would suggest using more tuning states, or reconfiguring the antenna structure in response to sensors already available in wireless devices.

The industry is also looking to further reduce the antenna instantaneous bandwidth for subband operation through the use of closed-loop feedback. These approaches are not for the timid, as they involve the use of active components, which introduce concerns over nonlinearity, stability, response time, power handling capability, ESD compliance, and test methodology.

The choice of active components used for tuning depends on the number of tuning states, the specific antenna design, the frequency range to be covered, harmonic generation requirements, and control interface capability. Tuning can be implemented within the matching network or within the antenna itself to directly control its resonance frequency.

Ultimately, to mitigate the effects of various usage models, it may be necessary to combine the benefits of state tuning and mode isolation. Modal isolation reduces mutual coupling and correlation coefficient, while state tuning allows operation of the antenna over the necessary range of frequencies for a given space allocation and modal volume.

Conclusion

Significant challenges exist for antenna designers to meet the needs of modern wireless devices, which will rely on implementation of MIMO protocols over an increasing spectral range. Requirements to support lower frequencies associated with newer band allocations in the United States, as well as the need to add additional antennas, place significant design constraints on existing smartphone industrial designs. Usage models will likely drive more advanced antenna designs that reconfigure to meet specific operational modes.

***About the Author:** Frank M. Caimi, PH.D. is Chief Scientist at Skycross and also serves as a consultant on communications and signal processing for industry and government organizations.*

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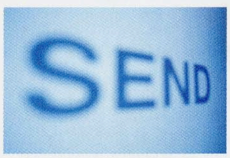

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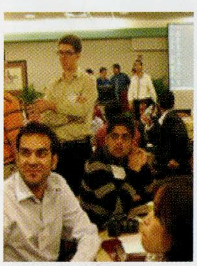

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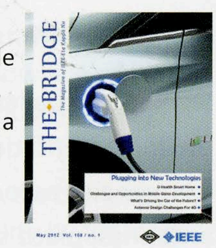

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