

Tomorrow's Technology Today

Have you noticed the subtitle “Tomorrow’s Technology Today” on the front page of each issue of *IEEE Spectrum*? To me, this phrase gives the positive message that we engineers continue to deliver exciting new technical solutions and products to benefit society at large as well as individuals. It also says that we are not at all at a saturated or stagnated stage; rather, there are plenty of opportunities for innovation around us. I also want to read it as an invitation to learn new things and initiate new technology-related projects in my private and professional life.

While writing this article, the sixth book in the the Harry Potter series, *Harry Potter and the Half-Blood Prince*, was released with worldwide media coverage. For Harry, anticipating the future is, in principle, easy. His third-grade textbooks at the Hogwarts School on Witchcraft and Wizardry included “Unfogging the Future” [1]. Why do I take this highly imaginative character up in this text? The reason is the imagination of the author herself. I find it interesting to read about all the mysterious devices and functionalities she has innovated in this wizardian world. I do not know whether she got the idea of almost-living paintings from flat-panel displays, or whether she is aware of three-dimensional (3-D) recording and display technologies or GPS-equipped tags that could be used to implement some other functionality found in the books. Nevertheless, she seems to have a rich imagination for painting convenient solutions from which real people would benefit as well. This is a very desirable characteristic of engineers involved in R&D.

In many of the recent Internet, music player, and cell phone innovations, the

novel part is in making a digital service more convenient and easy to use. Here, technology is an enabler, but the innovation is based on understanding and predicting the evolution of user needs. Gaining foresight on this softer side of product development is an important but very challenging task. For me, the simple word “convenience” rather well describes the general direction. Obviously, the fields of social and behavioral sciences can give scientifically solid guidance for this kind of human-centric “soft” problem. I feel that in this area there is some sort of a communication gap between the social sciences and the engineering world. Narrowing it would be in the interest of both sides.

As the fourth view to gaining foresight and fostering innovation, I want to take up the formal approaches developed by the strategy and innovation researchers at business schools and research institutions. Asking the right types of questions and being able to formulate the problem properly can produce significant wisdom and guidance. Working in a systematic way and using experiences from the past, one can build a significant amount of wisdom on the choices available. For instance, the book of Christensen et al. [2], with a Harry-Potter-style title *Seeing What’s Next*, can provide valuable guidance for developing a company’s product and business strategies.

It would be interesting to try to adapt the structured approach used in the business world to the research environment. I feel that, when properly applied, this can give some valuable guidance to a basic researcher seeking a new or modifying an existing avenue of research. The method should also be able to increase the long-term industrial relevance of research results.

BALANCING BETWEEN BROADENING AND FOCUSING

While innovation is ultimately a very personal capability, it is highly influenced by the space where one operates and has operated mentally as well as physically. During one’s career, technologies come and go. This calls for a continual curiosity and desire to learn new

The author of this article, Dr. Yrjö Neuvo, senior vice president and technology advisor at Nokia, gives us some advice from his unique working experience, first as a professor internationally active in signal processing research and then in a major industrial management position responsible for mobile phone product development. This article takes a refreshing and energizing look at foundations of engineering innovation both from an individual and organizational point of view. The author’s recipe for success is focused knowledge combined with broad sensor network, and child’s play combined with tight project timelines and discipline. There is a lot of the academic side can learn from industry, and vice versa. In addition, cooperation benefits both parties in terms of new knowledge. Valuable guidance is given for managing research renewal and creating multidisciplinary research projects. The author recommends that young engineers acquire a broad experience base, stretching one’s limits before “settling down.” I hope you enjoy this article and learn something to help develop tomorrow’s technology today.

—Arye Nehorai
“Leadership Reflections” Editor

things. There is also no substitute for deep knowledge of your subject matter. It is a bit amazing how well the scientific foundations that one learns at the university seem to carry over in one's career life. They help in acquiring new competencies and understanding the essentials of new technologies.

In addition to hard knowledge, one cannot overemphasize the importance of having and maintaining a natural informal communications network. This network provides food for thought and enables even rather strange-sounding combinations of information to be made. This kind of networking can only work in both directions. You get roughly as much as you are able to give.

Today there seems to be high expectations that new innovations are born at the borderlines between sciences. That may well be so. Maybe I am old-fashioned, but I do feel that multidisciplinary research is best conducted by teams composed of experts in bordering disciplines rather than somebody trying to be an expert of the borderline. Similarly, in education, it is important first to learn the scientific principles of a certain field of engineering. Later, one can take courses broadening the scope and preparing for participation in multidisciplinary projects.

There still is the interesting and rather fundamental question: what kind of disciplines, when put together, make good multidisciplinary projects? How close to each other should these disciplines be? What combinations have the most potential for scientific or industrial breakthroughs? Ideally, it would be interesting to define some kind of a metric describing the distance between two disciplines. This would obviously be quite subjective due to the complexity of the problem. However, being only able to list and elaborate some relevant attributes would already be an interesting step forward.

I personally tend to see more value in projects comprising relatively "closely" connected disciplines. DSP, communications, CMOS integration, and computing research would make a good multidisciplinary team for me. Obviously, quite a lot of progress has already been made in

this area. On the other hand, quite a lot of progress remains to be made within each of the disciplines, and there is no doubt that the combination is of industrial interest. As another example, I would like to take the area of multimedia, where deep knowledge of signal processing, certain areas of pure mathematics, and auditory and visual perception could still bring real breakthroughs.

PLAYING, BUT WITH DISCIPLINE

Even though there are many ways to formally acquire new knowledge, most still comes through learning by doing. My experience from both academia and industry indicates that the best innovators often take their work almost like their play as children. Separating work and leisure is often difficult but not so much an issue when you like what you do. What do children do while playing? Playing often means constructing something from some sort of blocks. Alternatively, it could mean a competitive game. In addition, there is no doubt that playing teaches social skills and teamwork.

Good R&D engineers can be said to be a bit childish. They like to construct tangible things that work and can be shown as one's achievement. Thus, it is often good to formulate even abstract tasks to be part of a demonstrator or proof of concept. These are also good ways of energizing multidisciplinary project teams. Competition is always present in industry, and it is translated to R&D projects in the form of tight timelines and technical performance requirements. Obviously, achieving and competing are essential parts of the academic world, but they are not always as visibly present as in industry. Getting a paper accepted, receiving an award, getting a degree, or being promoted are ways to create competition and give recognition in the academic world.

Projects are also a good way to create teamwork and competition in universities. In addition, successful demonstrators are an excellent way to get the media interested in university research. Popularizing science and technology is something we cannot overdo. During my

years as a professor, my students and I actively participated in the Micromouse [3] contests, which were originally introduced in 1977 in *IEEE Spectrum* and further refined in the United Kingdom. In addition to providing exciting and effective teamwork in a multidisciplinary environment, the contests also taught the importance of keeping deadlines. The project had to be ready by the contest date. Being one day late ruined the work of several person years by the team. Later on, we ended up in a contract research project developing a speech coder for the GSM standard. The entrant codecs were competing against each other in speech quality, latency, and complexity. For us, this was an ideal case to put our academic knowledge of signal processing into action. We met the deadlines but did not win the competition. The project, though, taught us many new things, and one could say that it kind of solidified our knowledge base in speech coding.

In industry, a well-defined product development process is key to success. This is the tool that tells how to partition complex tasks that require busloads of engineers into well-defined and manageable subtasks and milestones. A good process continuously gives information about the progress being made, provides warnings about potential bottlenecks, and enables the project to be finished on time with efficient use of resources. The great thing about the product development process is that it provides a structured framework to get organized and work effectively. This frees the engineers to work on the more innovative aspects of product development. In basic research, things cannot be structured up to the level of product development. The goal is often not as strictly defined and the complexity is lower, as basic research teams tend to be rather small. However, even for a single-person team, structuring the work properly and setting up challenging targets as clearly as possible strengthens motivation and innovation.

STABILITY VERSUS STORM

The performance of the organization is continuously being challenged by competition in the marketplace. In industry,

competition is visible every day. As a result, companies are continuously updating their product portfolio and revitalizing their organization. In a dynamic industry, significant changes tend to happen almost annually. In the academic world, the situation is a bit different. Once you have created a world-class competence in a certain field, you can continue publishing and getting academic credits by producing incremental improvements. The topic itself may have become almost completely obsolete in terms of any potential major breakthroughs and industrial relevance. My estimate is that the time constant of renewal in the industry is of the order of a few years. In academia, it obviously varies considerably, but it can be a few decades. This is understandable to a certain degree. However, if the research is gradually approaching a dead end, it inevitably means a certain loss in resource utilization. This also reduces the chances of participating in major research projects and hampers the relevance of education.

On the other hand, if an established researcher moves to a promising new research area, it takes at least a few years before he/she is again productive in terms of papers/year and other academic figures of merit. This is not generally tolerated by the funding agencies.

When discussing the dilemma of research renewal with a colleague of mine, a linguistics professor, he gave me a very simple rule of thumb that one should try to follow. Imagine that you are standing with your feet together. The area your feet cover represents your current area of research. Roughly every fifth year, you should move one foot as far as possible. Keeping the other foot in place means that you continue the research where you already are productive. The place of the repositioned foot denotes the new research area that has to be within a certain comfort zone from your current research but still radical enough. This way, you do not lose too much of the

productivity in your current area of excellence. Experience shows that opening up a new research area in this way can have a strong revitalizing effect for the whole team. By placing a foot where one can also see longer-term industrial or societal relevance rapidly overcomes the shortcomings that arise from cutting your research effort in the current area of excellence.

INDUSTRY AND ACADEMIA

It is very clear to me that in industry-academia cooperation both parties benefit. The cooperation is based on wrong premises if the parties think that industry gives the money and academia the wisdom.

Definitely, this cooperation does not lessen the value or put limits on basic research. In a good research group, basic research provides a continuous feed of ideas to more applied joint research projects. At the same time, one gains understanding of the challenges from the industry. This adds relevance to teaching, motivates the researchers, and helps in innovating and formulating new basic research projects. On the other hand, universities bring new research results to the table and have the arsenal for attacking difficult problems in a rigorous, scientific way.

Creating patents in cooperative projects is relatively easy. Having the industry on board from the very beginning increases the relevance of each patent and often helps in the patenting bureaucracy.

For a young person, I definitely recommend acquiring a broad experience base before "settling down." This can mean studying abroad or working both in the industry and academia. Stretching your limits is something you will not regret later, even if it calls for some sacrifices in financial status and living comfort. For me, it is now easy to say that studying abroad helped me greatly in establishing signal processing research in Finland. I moved to work in industry rather late, at the age of 50. I feel privileged having had the opportunity to

work on both sides. This has been a marvelous experience.

People often ask me how I could leave the academic world and how the academic and industrial worlds compare. Obviously, many of the fundamentals are the same or are very similar. Some of them I have touched upon in this article. There are also topics that are more or less "orthogonal." Even the conferences and exhibitions one attends are surprisingly disjoint.

From my life experience point of view, I imagine both being presented by an experience vector of equal length and having an angle between them less than 90°. Thus, the overall life experience vector is at least 42% longer than either one alone.

AUTHOR



Yrjö Neuvo received his doctoral degree in electrical engineering from Cornell University. He is a senior vice president at Nokia Corporation and a member of the Nokia

Group Executive Board. He has made a significant academic career as a professor in Finland and the United States prior to joining Nokia in 1993. Over the years, he has established over 400 technical articles and is holder of several patents. He has been chairperson and member of several international research policy-related committees and working groups. For his scientific contributions, he has been awarded recognitions from a number of international bodies including Academia Europaea, and the Royal Swedish Academy of Technical Sciences, and three honorary doctorates. He is a Fellow of the IEEE.

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