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Retrospections of an Engineering Educator

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In this article, the author summarises his retrospections as an engineering educator for nearly 40 years, as well as his partnership with the UNESCO International Centre for Engineering Education (UICEE). The paramount importance of close industry links for engineering students and academic staff is illustrated by his personal experiences. A case study of a new decomposition method for complex logic networks exemplifies that university teaching and research are inseparable. The joys of leading an academic department or school, such as making a difference to engineering education by introducing new courses or recognition by students, are followed by a summary of the author's UICEE publications on Field Programmable Gate Arrays (FPGAs), industry certification programmes, wireless networks and virtualisation.

INTRODUCTION

Four decades before the three-time Pulitzer Prize winner, Thomas Friedman, published his book, called *The World is Flat – a Brief History of the Globalized World in the 21st Century*, on the astonishing pace of globalisation in the 21st Century, the author of this article had the opportunity to experience how easily the engineering education can cross the national borders [1].

The author began an engineering course at the Technical University of Lodz in Lodz, Poland, but completed it at the Technical University of Dresden in Dresden, Germany.

Over the years, the author experienced first hand the strengths and weaknesses of engineering education in Europe, Africa, Australia and Asia, and witnessed the breathtaking development of Information and Communication Technology (ICT).

Some of the technologies, such as microprocessors, the Field Programmable Gate Arrays (FPGAs), the concept of Virtual Machines and the Internet, have created new and exciting opportunities for engineering education.

This article is an attempt at summarising the author's personal experience as an engineering educator, as well as his partnership with the UNESCO International Centre for Engineering Education (UICEE), which is based at Monash University, Melbourne, Australia.

THE IMPORTANCE OF INDUSTRY LINKS IN ENGINEERING EDUCATION

Close links with industry are of paramount importance for both engineering students and academic staff. In the 1960s, the author's studies, both in Poland and Germany towards a Master of Electronic Engineering degree required 11 full-time semesters, including significant industry experience: 91 weeks of industry placements and engineering projects.

One of the most interesting and challenging component was a 26-week engineering practicum. A year before graduation, students were expected to work at leading companies or research centres solving complex engineering problems. The author spent six months at the German Academy of Sciences in Berlin developing a high precision digital-to-analog converter for a Mössbauer spectrometer. Nowadays, such a converter could be implemented on a single chip costing just a few dollars, giving a good indication of the progress in the VLSI technology since the late 1960s.

So how did the engineering courses in Poland and Germany compare? While the Polish technical universities offered excellent foundations in mathematics, physics, electrical circuits and other theoretical subjects, the strengths of the German counterparts lay in excellent student laboratories and an emphasis on professional, industry-oriented courses. Another important skill that students had to learn was the ability to work within a team. Therefore, completing the first two years in Poland (rather than just the first year in case of the author) and continuing studies in Germany would have optimised the strengths of the two fine – but distinct – systems of engineering education.

The 91 weeks of industry placements and numerous practical projects had a life-long impact on the author's professional career. He has since used every opportunity to work on industry projects or work full-time in industry. While being an academic in Warsaw, he was also in charge of the following fully implemented projects:

- TV scanner for digital signal processing;
- Multi-computer adapter for ICL-1900 mainframes;
- Hardware monitor for the measurement and evaluation of mainframe performance.

Accepting a full-time position as Head of a CAD/CAM Research and Development laboratory at the Polish MERA Corporation created a unique opportunity to learn the newest minicomputer and microprocessor technologies, not only there but also at its licensing partner, the ASEA Corporation in Sweden (now ABB). The author recalls the two years of industrial experience at MERA as one of the most productive and enjoyable periods of his professional life. It also led to being offered an attractive contract at the Higher Institute of Electronics in Malta, where the author could combine tertiary teaching with the management of a computer centre.

Since arriving in Australia in 1984, the author has continued to encourage students to gain as much industrial experience as possible during vacation months, with or without pay. A graduate with a relevant employment record has a better chance of being employed by a small or medium-sized company, which will more than often be looking for a person with specific industry experience.

Government Employment Initiatives

There are a number of Commonwealth or State Government initiatives to help students find employment. One of the Australia-wide industry placement schemes is the Cooperative Education for Enterprise Development (CEED) Programme [2]. Since Edith Cowan University (ECU), Perth, Australia, joined the programme in 1990, a few hundred of the brightest and best ECU students have been placed in more than 100 organisations around Perth for one or two semesters to complete a final year project. In 2005 alone, 17 students participated in the Programme. According to an agreement with the Australian Computer Society Foundation, every CEED student from the ECU becomes an ACS Scholarship holder and is guaranteed a job interview after graduation.

A Western Australian Government scheme, known as the Science and Innovation Studentship Award, helps up to 20 students each year to work on a research project in the private sector during 10 vacation weeks [3]. In 2005, three ECU students benefited from this scheme.

THE IMPORTANCE OF RESEARCH IN ENGINEERING EDUCATION

The following case study illustrates the generally accepted wisdom that university teaching and research are inseparable. A research completed at the University of Western Australia has led to the development of a two-stage decomposition algorithm for complex logic networks [4]. The practical importance of the research was not only tested on a number of high speed digital circuits but also became an integral part of an undergraduate unit in Digital Electronics at the ECU in Perth.

Interest in a two-stage decomposition of logic networks was prompted by the needs of real-time grey-scale morphological processors. Such processors required a fast implementation of two conflicting operations:

- Additions/subtractions;
- Maximum/minimum searches.

The conflict resulted from the characteristic of conventional arithmetic systems, which required opposite directions of digit processing: the least significant digit first for addition/subtraction; the most significant digit first for maximum/minimum search.

High speed data processing and a regular circuit design was achieved by applying the principles of digit-level systolic arrays. However, the conflict resulting from the characteristic of the conventional arithmetic systems made the implementation of a digit-level systolic array impossible.

The problem was solved by applying the Signed Digit Number Representation (SDNR). The SDNR allowed a uniform direction of addition/subtraction and maximum/minimum search – from the most to the least significant digit.

SDNR systems are more difficult to implement in hardware than conventional arithmetic circuits. Boolean functions, which define the SDNR systems, are more complex and have a larger number of independent variables. Therefore, a two-stage decomposition algorithm was required, as follows:

- Arithmetic decomposition based on SDNR/RNS data representation;
- Boolean decomposition based on partition products.

Stage 1, the arithmetic decomposition applied a novel data type – a combination of the Signed Digit Number Representation (SDNR) with the Residue Number System (RNS). If the complexity of a decomposed network was still too high for an implementation technology, such as FPGA or PLAs, Stage 2, the Boolean decomposition of multiple-valued Boolean functions followed.

The two-stage decomposition process leads to a unified hardware structure, suitable for a wide range of linear and non-linear systems, such as FFT, encryption devices, rank order filters and morphological processors. It was applied to high-radix arithmetic systems, which could not be implemented using conventional methods.

A reduction of hardware complexity was reduced by factors of 2-3 when compared to designs generated by commercially available CAD systems.

When Edith Cowan University (ECU) launched the Bachelor of Engineering awards in Computer, Communication and Electronic Systems in 1992, one of the new student facilities included a Digital Electronics Laboratory. The conventional, time consuming and expensive circuit building, based on printed circuits, discrete electronic components, wires and soldering, was replaced by generic VLSI technology – the Field Programmable Gate Arrays (FPGAs) [5][6].

A commercial design package worked well for short-term experiments and projects. However, the FPGA implementations of the final Pass and Honours projects required a powerful decomposition method. The arithmetic decomposition based on SDNR/RNS data representation followed by Boolean decomposition based on partition products had been successfully applied, not only for the more complex final projects, but also for simpler, short-term assignments, confirming that research and teaching are indeed inseparable.

THE CHALLENGES AND JOYS OF MANAGING A UNIVERSITY UNIT

The challenge for a leader of an academic unit is how to share time between management, teaching and research. The joys include the opportunity to make a difference to engineering education and a potential recognition not only by university hierarchy but also by students and the profession.

Since joining Edith Cowan University, the author was elected Foundation Chairperson of the Department of Computer and Communication Engineering (1992-1997), coordinated research and postgraduate programmes in the School of Computer and Information Science (1998-2003), and was appointed Head of School of Computer and Information Science (2003-present).

Chairperson of the Department of Computer and Communication Engineering

Becoming a Foundation Chairperson of the first engineering department at Edith Cowan University presented a unique opportunity to create world class student facilities based on the newest technologies, such as advanced Field Programmable Gate Arrays (FPGAs), designing courses in communication, computer and electronic systems that were granted full accreditation by the Institution of Engineers, Australia, and initiating a number of research projects.

The author developed nine new engineering courses, including the first double degrees in the history of Edith Cowan University: BEng in Communication Systems; BEng in Computer Systems; BEng in Electronic Systems; BTech in Electronic Systems; Double Degree BEng/Bachelor of Arts; Double Degree BEng/Bachelor of Business; Double Degree BEng/Bachelor of Science; Master of Engineering Science by Research; Doctor of Philosophy.

The author wrote a successful proposal for the Centre for Very High Speed Microelectronic Systems and also contributed to its research effort [7-10].

Research and Postgraduate Programmes Coordinator

The most rewarding aspect of research and postgraduate programmes coordination was the recognition by Edith Cowan University students through their Postgraduate and Honours Students Association, including the 2002 Faculty Research Leader of the Year award:

- 1998 Award for Excellence in Research Supervision;
- 2001 Award for Excellence in Research Leadership;
- 2001 Award for Excellence in Postgraduate Supervision;
- 2002 Research Leader of the Year in the Faculty of Communications, Health and Science;

- 2002 Award for Excellence in Research Leadership;
- 2003 Award for Excellence in Research Leadership;
- 2003 Award for Excellence in Postgraduate Supervision.

The author also developed two postgraduate courses: Doctor of Information Technology and Master of Science (Computer Security) by Research.

Head of the School of Computer and Information Science

In 2003, the author took over the leadership of a large school with 1,730 students, including 354 postgraduates and 563 students from overseas (the largest international programme at the ECU) [11]. School achievements since 2003 include the following:

- Research productivity increase by 45%;
- A new professorial Chair in Computer and Information Security fully funded by IBM;
- Launch of an ECU Master of Information Technology programme at the prestigious Graduate School of the Chinese Academy of Sciences in Beijing, China.

LINKS WITH THE UICEE

The UNESCO International Centre for Engineering Education (UICEE) is the world's first institution to promote research and the practice of engineering and technology education on a truly global scale [12].

The Centre, under the tireless directorship of Prof. Zenon J. Pudlowski, has achieved remarkable successes in raising the profile of engineering and technology education on all continents, helping tertiary institutions in developing countries, and creating a remarkable international network of partner institutions, satellite centres, sponsors, supporters and members [13]. The unique atmosphere of UICEE-run conferences, where delegates not only share their passion for engineering and technology education but also establish friendly relationships with researchers from all corners of the globe, must be experienced to be appreciated.

The author is thankful to the UICEE for the opportunity to present papers on the four following major themes:

- Field Programmable Gate Arrays (FPGAs);
- Industry certification programmes;
- Wireless networks;
- Virtualisation.

Field Programmable Gate Arrays

The fundamental question of any programme in electronic engineering is how to incorporate various aspects of VLSI design, implementation and testing in the curriculum. While most design steps at the logic and circuit levels can be adequately trialled using standard VLSI design packages, the choice of a VLSI technology that allows students to implement and test their digital circuits quickly and inexpensively, remains a problem [5][6].

Field Programmable Gate Arrays (FPGAs) are an ideal platform for courses in electronic circuits and systems. The technology, together with a VLSI design package, enables students to experiment with designs at different levels: from design entry and functional simulation, down to in-circuit hardware verification. Since FPGAs store configuration data in Static Random Access Memory, modifications to prototypes are fast and cost-free. FPGAs introduce students to new exiting system design concepts, such as Internet Reconfigurable Logic (IRL), allowing for the quick deployment of performance upgrades or bug fixes for a digital system over the Internet.

Industry Certification Programmes

The Information Technology and Telecommunications (ICT) industry is characterised by unprecedented staff mobility. Major producers of computing and telecommunications equipment or powerful software development houses are truly international corporations which expect their employees to accept new positions on the far side of the globe. The university sector responds to the trend by introducing courses with some international flair in computer, communications or software engineering.

National course accreditation bodies contribute to the internationalisation of engineering courses. The Washington Accord is an example of mutual recognition of engineering courses at the professional level. However, truly international qualifications in Information Technology and Telecommunications are not offered by universities but by industry certification programmes, such as MCSE or CCNP [14-18]. These programmes are respected qualifications providing objective evidence of practical skills that are directly applicable to the needs of industry. Programme requirements are identical in all parts of the world, solving one of the fundamental problems of staff mobility – recognition of overseas qualifications.

Wireless Networks

The rapid development of wireless networks creates new opportunities for university teaching. For instance, conventional classrooms can be converted within minutes into computer laboratories providing access to local and remote databases, multimedia presentations, voice telephony and other resources. Students can bring laptop computers with wireless network cards to the classroom and gain access to the university network through wireless access points. Other benefits include access to the university library, online study groups or online enrolments from any place within the range of the wireless network [19].

Regular university events, such as enrolment days, require access to a secure network from a significant number of workstations. A cost effective alternative to a permanent infrastructure is the Highly Deployable Network, which can be quickly deployed in any temporary location, such as a gymnasium, lecture theatre, cafeteria, etc [20].

Virtualisation

Virtualisation, an important tool for server consolidation and software development, is also an exciting option for teaching courses in computer networks. A single personal computer plus Virtual Machine software can replace multiple servers, workstations, switches and routers. External students, without access to on-campus laboratories, can perform advanced networking experiments at home, such as: implementing a three-segment network with two routers, configuring a DHCP server, remote printing, monitoring the IPSec protocol, configuring a VPN server, etc [21][22].

The concept has also been successfully applied in on-campus network laboratories. For example, experiments with the redundant disk systems, such as RAID-5, replace multiple physical disk drives by virtual disks [23].

CONCLUSIONS

Thomas Friedman's recent book is a credible analysis of the astonishing pace of globalisation, especially the emerging of India and China as superpowers in Information Technology, telecommunications and other high-technology industries [1]. Large corporations, such as Microsoft, Cisco and IBM, have been moving to both countries, not only because of low manufacturing costs, but also for the huge intellectual potential that these countries represent.

The future of the UNESCO International Centre for Engineering Education will not be threatened by globalisation. On the contrary, the UICEE is already a positive contributor to the global society by sharing expertise in engineering and technology education.

REFERENCES

1. Friedman, T., *The World is Flat – a Brief History of the Globalized World in the 21st Century.* London: Allen Lane (2005).
2. Edith Cowan University, Faculty of Computing, Health and Science, Co-operative Education for Enterprise Development (CEED) (2004), http://www.chs.ecu.edu.au/org/int_comm/ceed/
3. Government of Western Australia, Department of the Premier and Cabinet, Studentship Award (2005), http://www.scienceandinnovation.dpc.wa.gov.au/index.cfm?event=studentshipAward
4. Kuczborski, W., Attikiouzel, Y. and Crebbin, G., Decomposition of logic networks with emphasis on signed digit arithmetic systems. *IEE Proc. Circuits Devices Systems,* 141, **4**, 307-314 (1994).
5. Kuczborski, W. and Cheung, H.N., Courses in digital electronics based on field programmable gate arrays. *Proc. 3rd East-West Congress on Engng. Educ.*, Gdynia, Poland, 422-425 (1996).
6. Kuczborski, W., The application of field programmable gate arrays in engineering education. *Proc. 3rd Global Congress on Engng. Educ.*, Glasgow, Scotland, UK, 319-321 (2002).
7. Mehnert, A.J., Eshraghian, K., Kuczborski, W. and Cross, J.M., *Image Coding and Compression Using Mathematical Morphology.* Perth: Edith Cowan University (1995).
8. Mehnert, A.J., Cross, J.M., Kuczborski, W. and Eshraghian, K., *A VLSI Processor for the Real Time Implementation of Mathematical Morphology Operations: Specifications.* Perth: Edith Cowan University (1995).
9. Mehnert, A.J., Eshraghian, K., Kuczborski, W. and Cross J.M., Image coding and compression using mathematical morphology: hardware implementation issues. *Proc. 4th UK/Australian Inter. Symp. on DSP for Communication Systems*, Perth, Australia, 308-315 (1996).
10. Mehnert, A.J., Burgess, N., Eshraghian, K., Kuczborski, W. and Sarmiento, R., A GaAs video rate morphological processor for image coding and compression. *Proc. European Gallium Arsenide and Related III-IV Compounds Application Symp.*, Paris, France (1996).

11. Edith Cowan University, School of Computer and Information Science (2005), http://www.scis.ecu.edu.au
12. UNESCO International Centre for Engineering Education (UICEE) (2005), http://www.eng.monash.edu.au/uicee/
13. Pudlowski, Z.J. and Darwell, P.LeP., UNESCO International Centre for Engineering Education (UICEE). *Global J. of Engng. Educ.,* 8, **1**, 9-30 (2004).
14. Kuczborski, W., A new approach to courses in computer systems and computer networks. *Proc. 3rd UICCE Annual Conf. on Engng. Educ.*, Hobart, Australia, 368-371 (2000).
15. Kuczborski, W., Can universities compete with IT industry certification programs? *Proc. 2nd Global Congress on Engng. Educ.*, Wismar, Germany, 287-290 (2000).
16. Kuczborski, W., A competency-based course in network design and management. *Proc. 2nd Global Congress on Engineering Educ.*, Wismar, Germany, 251-254 (2000).
17. Kuczborski, W., A case study of academia/industry collaboration: Microsoft Authorised Academic Training Program (AATP). *Proc. 3rd Asia-Pacific Forum on Engng. & Technology Educ.*, Changhua, Taiwan, 172-175 (2001).
18. Kuczborski, W., A new minor in network administration and design. *Proc. 6th UICEE Annual Conf. on Engng. Educ.*, Cairns, Australia, 77-80 (2003).
19. Kuczborski, W., Wireless networks create new opportunities for engineering education. *Proc.3rd Asia-Pacific Forum on Engng. & Technology Educ.,* Changhua, Taiwan, 141-143 (2001).
20. Kuczborski, W., Highly deployable wireless networks. *Proc. 3rd Global Congress on Engng. Educ.,* Glasgow, Scotland, UK, 356-358 (2002).
21. Kuczborski, W., A computer network laboratory based on the concept of virtual machines. *Proc. 6th Baltic Region Seminar on Engng. Educ.*, Wismar/Warnemünde, Germany, 145-148 (2002).
22. Kuczborski, W., The significance of virtual computer networks in distance education. *Proc. 6th UICEE Annual Conf. on Engng. Educ.,* Cairns, Australia, 163-166 (2003).
23. Kuczborski, W., A computer network laboratory based on the concept of virtual machines. *World Trans. on Engng. and Technology Educ.*, 4, **1,** 7-10 (2005).

BIOGRAPHY

Wojciech Kuczborski was born in Poland and began his engineering studies at the Technical University of Lodz. Upon graduating in electronic engineering from the Technical University of Dresden, Germany, he worked for 10 years as lecturer, project leader and manager of an R&D laboratory in Warsaw, Poland. After completing a five-year contract at the Higher Institute of Electronics in Malta and North Africa, he migrated to Australia in 1984 and completed his PhD in Computer Engineering at the University of Western Australia.

Currently, he is the Head of School of Computer and Information Science and Associate Professor at Edith Cowan University in Perth, Australia. He is a Fellow of the Institution of Engineers, Australia, a member of the UICEE and a member of the Australian Computer Society.