

Women Trailblazers in Clinical and Biomedical Engineering

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Abstract— History is paved with innovators in the field of biomedical engineering but most of them are well-known male figures. This paper will dive into four women innovators in biomedical engineering and clinical engineering. We will discuss their innovations, what drives them and what impact their discoveries or inventions had in engineering and clinical engineering. We will address the challenges each of the women faced in their field and how they used their influence to make a difference and leave a legacy into their respective disciplines. At the end of this paper, the reader will have enough examples of plenty of women innovators in clinical engineering and biomedical engineering, even though they are never taught in classrooms or in history books to convey the existence and many contributions of the women. Also, the reader will be more motivated to encourage women to enter, excel, and stay in this male-dominated field and share these successful stories. Representation of women innovators matters in society.

Keywords— Women in STEM, women in biomedical engineering, women in clinical engineering, women trailblazers

I. INTRODUCTION

History is paved with innovators in the field of biomedical engineering and clinical engineering but most of them are well-known male figures [1]. Women innovators in biomedical engineering and science exist except they are rarely published or discussed in public forums.

In Canada, women represented 39% of university STEM degree holders aged 25 to 34 in 2011 [2]. Only 22.5 % female of STEM graduates work in STEM occupation in 2016 and in 2019 [3], only 13.9 % women (42,305) are engineering members of a professional engineering licensing body [3].

The aim of this paper is to provide four examples of current women researchers/scientists that are moving the field of biomedical engineering and clinical engineering from the International Federation for Medical and Biological Engineering (IFMBE). The author is presently the co-chair of the Women in Biomedical Engineering (WiMBE) of IFMBE and wants to put in record the contributions of the outgoing women committee that created a pathway for women in engineering at IFMBE. This article will showcase their innovations, what drives them, and the impact that their discoveries or inventions have in engineering, science and medicine.

This paper will also address the challenges that each woman faced in their chosen field and how they used their influence to make a difference and leave a legacy on their respective disciplines.

The motivation of this paper is to provide considerable testimony that there are plenty of women innovators in clinical engineering and biomedical engineering and to encourage dissemination of this information into classrooms or history books. The aim at the end is to convey the contributions of these women and motivate and encourage more women to enter, excel and stay in these males-dominated fields. Sharing these successful stories and their struggles in society matters as the representation of women innovators influence the outcome of future women entering these fields.

We will be profiling four women trailblazers in biomedical and clinical engineering from around the globe involved in the IFMBE WiMBE committee: Virginia Ballarin (Argentina), Lenka Lhotska (Czech Republic), Fatimah Ibrahim (Malaysia) and Monique Frize (Canada). All the information collected in this paper was provided by these individuals in the form of short biographies, CVs and responses to a questionnaire and all consented to have their information published.

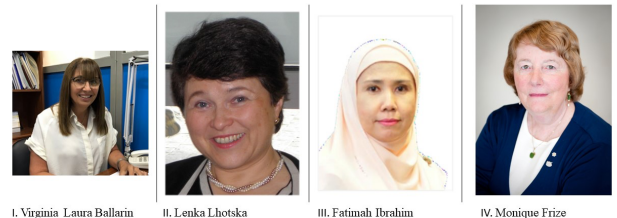


Fig. 1 Headshots of 4 women trailblazers discussed in this paper.

II. VIRGINIA LAURA BALLARIN

A. Short Biography

Virginia Laura Ballarin (Fig. 1: I) is an electronic engineer and has a PhD in bioengineering. She is Full Professor in the Signal Processing department at the Electronics Engineering Department of the Universidad Nacional de Mar del Plata, Argentina and Director of the Image Processing Research

Group at Research Institute of Science and Technology in Electronics in Mar del Plata, Argentina [4].

She has directed more than 20 PhD theses and 25 undergraduate theses, all in the biomedical image processing field. She has authored more than 75 papers in referred journals and more than 130 conference presentations. She has been involved in many committees in Institute of Electrical and Electronics Engineers (IEEE) and in IFMBE. Recently she was the past co-chair of the committee of Women in Biomedical Engineering (WiBME) of IFMBE from 2016-2022. She has been Secretary General of the Latin American Council of Biomedical Engineering (CORAL) from 2020 to 2022. Nowadays she is Vice-President of CORAL and Administrative Council member of the IFMBE 2022-2028. She has been member of several Peer Committees in Academic Program Evaluation of Graduate and Postgraduate Careers for Argentina, Uruguay, Paraguay, Bolivia, Colombia, and Costa Rica in the Regional Accreditation System for Higher Education in Mercosur and Associated States System since 2008 [4].

B. Motivation and Impact

Ballarin's foremost innovation was the development of application software for sperm motility analysis that includes not only the traditional image sequences motility tracker, but also clustering and classification modules for sperm subpopulation analysis. Although the problem of interpretability in Machine Learning affects the confidence of users in learning systems for Artificial Intelligence (AI) and is closely related to many ethical problems, interpretability is a desired property for deep neural networks to become powerful and applicable tools in the field of healthcare. That is the reason the lab under her direction is focused now in this research area.

She is driven to pursue and stay in this field because she loves engineering and solving problems. The most exciting thing for her is when she sees her developments directly influence people and their well-being, that keeps her staying and loving to contribute to the Biomedical Engineering field.

The impact of her work in the field is that biomedical engineering today is so complex and interdisciplinary that her research works turns out to be a small gear in the development of knowledge. However, she thinks her facility for interdisciplinary work is one of her greatest virtues, which allows a greater impact in each small step, especially in the study of the interpretability of AI and its applicability.

C. Challenges and Influence

In Ballarin's opinion, science is just another area of society crossed by gender inequalities. She asks: "How is it possible that inequalities exist in a space where reason should reign?" There are many factors that make it difficult for

women to develop a scientific career under equal conditions. Beyond overcoming stereotypes and choosing a scientific career, women still must bear more family burden today and, in a world as competitive as the scientific one, this weighs heavily. Despite this, in the biomedical scientific and academic world, objectivity and impartiality prevail, although there is still a small gender bias today [5].

She finds it is necessary to continue working for gender equality and reinforce the importance of having models. Still today, there are many women who cannot even choose their profession. She actively participates in the WiBME of IFMBE and Women in Engineering Affinity Group WIE of the IEEE. Both institutions work to increase the visibility and participation of women within engineering and to improve the climate for women in their workplaces.

She claims that we must educate girls who, when choosing their future, know that there are no limits, and boys who respect them and accompany them on that path. She also thinks that there are already signs that marks a change in this sense. We have come a long way as a society, but we still have a long way to go. "The world needs science and science needs women"[5].

For balancing work and life, Ballarin always demanded more of herself than others did, maybe that was because of her father's example. Models lead the way and family marks you deeply, she insists. If your parents don't trust you, any path becomes less possible or harder. She also states the partner you choose for your life is another fundamental person for a woman to be successful. If you were raised believing that you can be successful, and your partner accompanies you in your professional life, you will achieve it. You can love someone who allows you to grow, develop and be happy and fulfill also in a professional sense [5].

III. LENKA LHOTSKA

A. Short Biography

Lenka Lhotska (Fig. 1: II) graduated as Master of Science in Electrical Engineering at the Czech Technical University in Prague (CVUT), Czech Republic and got a PhD degree in Cybernetics from CVUT. Currently she is head of the Cognitive Systems and Neurosciences Department at the Czech Institute of Informatics, Robotics and Cybernetics and deputy head of Department of Natural Sciences of the Faculty of Biomedical Engineering, CVUT [6].

She supervised 20 PhD theses and is the principal investigator of more than 15 local and international projects. Her research focus includes knowledge-based systems, application of artificial intelligence (AI) methods to medicine,

digital signal processing, machine learning, semantic interoperability, mobile technologies in healthcare, and the electronic health record. She is the scientific secretary of the Czech Society for Biomedical Engineering and Medical Informatics, a national representative of IFMBE, member of Council of Societies of IFMBE, past co-chair of the WiMBE working group of IFMBE, and chair of the Women in Medical Physics and Biomedical Engineering of IUPESM (International Union for Physical and Engineering Sciences in Medicine). She is also a part of multiple European associations that include chair of the Working Group Personal Portable Devices of European Federation for Medical Informatics (EFMI) and member of the EFMI Council, and National representative in International Society for Telemedicine and eHealth (ISfTeH). She was co-chair of the IUPESM World Congress 2018 [6].

B. Motivation and Impact

Lhotska says thanks to her PhD students she is involved in several important areas, namely motion analysis using unobtrusive technology (sensors, cameras) most suitable for the target applications; machine learning methods for classification and prediction in medicine (focus: long-term multidimensional biosignal analysis); virtual reality and eye-tracking. What drives Lhotska in her research is new challenges, new technology that opens new ways both in diagnostics and therapy and the readiness for collaboration from the new generation of medical doctors.

The impact of her research is that some of her results are used in clinical research (not yet in full practice because of the long procedure of medical device certification). The use of her results in medical education as two examples of practical utilization of eye-tracking are: in ophthalmology for training children with diagnosed strabismus (combination of a game on a computer monitor with eye-tracking used for control of the game), and for detection of dyslexia in preschool age [7].

C. Challenges and Influence

While Lhotska is successful, there are many challenges women like her faced such as comments that are more general as "woman in engineering???" - "What is she doing here? She cannot understand the topic." Or when some women face problems in their jobs, when they achieve better results than their boss (usually a man). It seems to Lhotska that some men are afraid that women want to replace them, mostly this thought is not founded in facts. Unfortunately, this 19th century attitude is still present in many companies and even universities. Although the universities have developed and

presented the Gender Equality Plans, in many cases, it is purely a sheet of paper [7].

Lhotska manages well family and work at her current age as it is relatively simple because there are no small kids. In two career partnership she states it is an agreement on how much time the couple wants/must devote to work and how much time they want to spend together.

She knows the situation of younger colleagues who have small kids (preschool or primary school), where it usually depends on whether the partner has also a demanding job or whether the family has grandparents who can care for the grand children, and/or how the partners can/want to share the duties in the household [7].

IV. FATIMA IBRAHIM

A. Short Biography

Fatimah Ibrahim (Fig. 1: III) is an electrical engineer and has a PhD in biomedical Engineering from the University of Malaysia. She is a full professor at the Biomedical Engineering Department of the University of Malaysia and head of the Center for Innovation in Medical Engineering. Her research interests include detection and monitoring of infectious diseases and foodborne pathogens, carbon MEMS (Microelectromechanical systems)/NEMS (Nanoelectromechanical systems) biosensing, diagnostics, bioinstrumentation, artificial intelligence, and Internet of Things (IoT) integration in medicine as well as physiological measurement and modelling. She has supervised 23 PhD and 27 Master students. She holds more than 150 journal publications, more than 100 conference proceedings, more than 35 book chapters contributions and is involved in more than 20 different committees. Three of her patents have been commercialized and licensed by industries. The products are soon to be in the market. Some of her designs include: A Smart Wearable Device for Monitoring Low Back Pain Rehabilitation, Modular Bed Alarm System, Multi-Frequency Biological Impedance Measurement Device, and Method and Polymer platform for bio sensor application. Fatimah is actively consulting companies and trains her staff for commercialization and medical product registration. She has been an advisor and stakeholder for the Ministry of Health in Malaysia in the formation of the Malaysia Medical Device Act 2012. She has received more than 50 awards including, most recently, the Laura Bassi award from IFMBE [8].

B. Motivation and Impact

One of Ibrahim's successful innovations is Smart Portable Multi-Frequency Bioimpedance Analyzer for Disease

Monitoring (SmartMF). SmartMF is a non-invasive and portable device that can be used for general body composition measurement and to assist healthcare practitioners monitoring disease progression and treatment regimes. The SmartMF provides a direct readout of the impedance of the human body and estimates the mass distribution and body water compartments. These are key indicators of health and vitality which increase the certainty of an accurate assessment for the healthcare personnel to develop and prioritize nutrition and supplement programs. Studies have shown that these key indicators are also capable of providing an accurate assessment of health status for monitoring and management purposes in critically ill HIV patients [8].

Ibrahim's passion in doing research in biomedical engineering and determination comes from wanting to impact the society with her research work for the betterment of healthcare. She hopes that her innovation in biomedical engineering has contributed to providing better diagnosis and solutions for the problems faced in the field of biomedicine [8].

C. Challenges and Influence

Ibrahim believes the most challenging thoughts women face in their career are conservative viewpoints on women's capabilities in performing the engineering work and gender bias by the male colleagues. She hopes by sharing her talks in session as keynote/plenary speaker in public/conference/workshop, mentoring session to young engineers and scientists at various levels of organizations and institutions will influence the men and women in biomedical engineering to change their thoughts of women in STEM fields. She also believes in order to leave the legacy; the research work needs to be commercialized and the technology needs to be transferred into the industry. She already has 3 of her intellectual properties licensed by the industries and soon they will be available in the market. Thus, she believes research should work to become available to the public to use/purchase to make an impact to the society and world [9].

Ibrahim balances family and work very well. She has 4 children (3 boys and 1 girl) and although it is very challenging, with smart time and work management she manages to distribute the tasks. The most important element she says is to know and to prioritize the tasks at home and work. Identify the tasks that can get assistant and delegate the work. Hence, she believes you will have time to balance family and work. For example, household work such as cleaning and mopping the floor at home should be delegated to weekly paid support. On the other hand, household task such as cooking she recommends doing it together as this activity brings your family closer together [9].

V. MONIQUE FRIZE

A. Short biography

Monique Frize (Fig. 1: IV) was the first woman to obtain a Bachelor of Applied Science from the University of Ottawa, in 1966, and afterwards pursued her graduate studies in Canada, England, and the Netherlands. She worked for 18 years as a clinical engineer in Quebec and New Brunswick in Canada. As a professor of electrical engineering, she became the first holder of the Northern Telecom/NSERC (Natural Sciences and Engineering Research Council of Canada) National Chair of Women in Engineering at the University of New Brunswick in 1989. In 1997, she joined Carleton University as a professor in the Department of Systems and Computer Engineering, and the University of Ottawa as a professor at the School of Information Engineering and Technology. She held the NSERC/Nortel Research Chair in Women in Science and Engineering from Ontario until 2002. Moreover, she is a founding member of the International Network of Women Engineers and Scientists (INWES) and was its President from 2002 to 2008. Additionally, she was President of the Education and Research Institute (ERI) from 2007 [10].

As a researcher and engineer in the biomedical field, Monique Frize specializes in the development of medical instruments, medical imaging, and clinical decision support systems for the NICU, helping both physicians and parents to make decisions for their infants. She is the author of numerous scholarly publications and scientific papers presented at international conferences [10].

Throughout her career in engineering of more than 40 years, Frize has been proactive in the advancement of women in Science, Technology, Engineering and Mathematics (STEM). As a role model for women engineers, she has taught, conducted research, developed programs, and led campaigns to encourage young women to pursue careers in this field and has been widely recognized for doing so. In her book, *The Bold and the Brave*, she charts the history of women in science and engineering down through the centuries and highlights the obstacles that women have faced in pursuing such studies [10].

Frize has received several honorary doctorates and prestigious awards in recognition of her significant achievements. Among others, she received the Gold Medal from the Professional Engineers of Ontario and the Ontario Society of Professional Engineers, as well as being inducted as a Fellow of the Canadian Academy of Engineering, and as an Officer of the Order of Canada [10].