

WEN-HUA CHEN

Q. How did your education and early career lead to your initial and continuing interest in the control field?

Wen-Hua: I came to the control field purely by accident. I was born and grew up in a small village in eastern China. During my childhood, we lived in extreme poverty; we not only lacked food and other basic essentials

but also books. My dream job was to become a librarian so that I could not only earn a living but, more importantly, gain free access to books. This was part of the reason I almost failed my first-year university exams, as I spent too much time in the university library reading irrelevant topics.

When I entered high school, the Cultural Revolution had just ended. Before then, attending university was banned. I failed the university entry exam, partially because the school I attended lacked resources,

and I spent class time reading handwritten copies of fiction that were just becoming available underground and were prohibited. Actually, no one in my high school class, including one of our teachers who took the same exam, passed the entrance exam. I did enjoy my time there, though. Thanks to my parents, I was readmitted to another, much better, high school. When completing the university application form, I had no idea about the subjects the university was offering and how they linked with my future career;

Digital Object Identifier 10.1109/MCS.2018.2851006
Date of publication: 18 September 2018

I just wanted to get out of poverty. The subject of industrial automation sounded very fashionable, so I picked it. This was how I ended up in the control field.

I completed my bachelor's degree at Jiangsu University. University life had a tremendous influence on my interests in the control field and, more broadly, on my career and personality. It was a real eye-opening experience for a young man like me coming from a highly closed countryside. We were not only studying technical modules but also gaining exposure to a much wider range of extracurricular topics like music, philosophy, and art. After losing the right to teach for more than ten years due to the Cultural Revolution, professors and lecturers at the university put all of their efforts into teaching us and developing our skills. This, together with peers with similar backgrounds and desires, provided me with a wonderful learning environment and made courses both interesting and immersive.

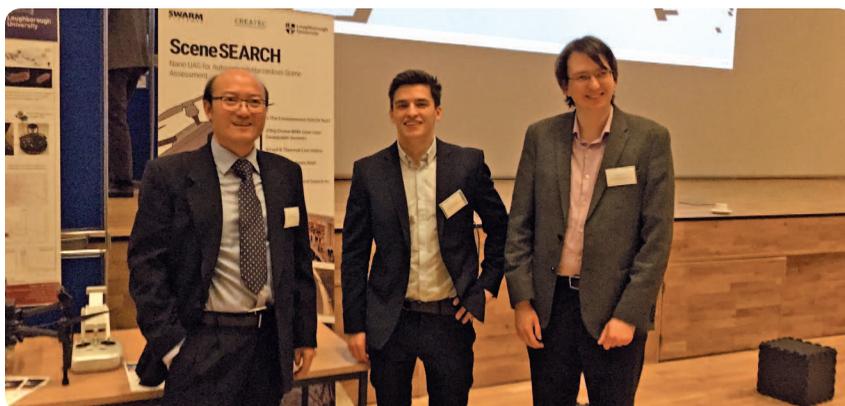
I completed my final-year project on ac motor speed control under the supervision of Prof. Liming Wang. Combined with a number of control modules I studied, this made the control field quite attractive to me. After my undergraduate studies, I entered Northeastern University to carry on my postgraduate studies on the same subject. I completed my master's and Ph.D. degrees with Prof. Shijun Lang and Prof. Xingyun Gu on the intelligent control of electrode systems of arc furnaces and robust control using game theory, respectively. At this stage, it dawned on me that the control field was the right area for me. The undergraduate university courses provided solid professional training, while I learned how to do research at Northwestern University under the supervision of my two advisors and with the help of other members of the research group (such as Tianyou Chai, Jingxin Zhang, Wei Wang, and Ziqiang Lang). I was very lucky to study and perform research in one of the top research groups in control fields in China.

Q. What are some of your research interests?

Wen-Hua: Starting with advanced control systems, my research interests gradually spread into a wide range of application areas. Rather than designing a controller offline, model predictive control (MPC) exploits the ever-increasing computational power available to generate suitable control commands online based on real-time measurements. In the 1990s, I was at the University of Glasgow in the United Kingdom working on applying MPC to mechatronic systems like robots that are intrinsically nonlinear and have fast dynamics. With an optimizer in the loop, the stability analysis of MPC (particularly for nonlinear systems) is interesting and

challenging. I have made a significant contribution in developing stability theory for nonlinear MPC. To address the real-time implementation issues of MPC on systems with fast dynamics, I also developed an analytical, nonlinear, MPC algorithm under certain conditions. Interestingly, it was also discovered that this nonlinear MPC law links with the feedback linearization technique.

During this period (while performing MPC experiments on robots), I experienced and observed challenges due to friction and parameter uncertainties, which motivated me to pioneer a now widely used nonlinear disturbance-observer design technique. Similar to the state-observer concept, a disturbance observer is designed to



(From left) Wen-Hua Chen with his Ph.D. students Michael Hutchinson and Pawel Ladosz at the showcase event of the U.K. EPSRC/Dstl University Defence Research Centres demonstrating the autonomous search of chemical/biological sources using robots and drones.



Wen-Hua Chen and his family on vacation in Lanzarote, Canary Islands.



Wen-Hua Chen at the top of Duomo Firenze, Florence, Italy, while attending the 2016 Annual Conference of the IEEE Industrial Electronics Society.

estimate unmeasurable external disturbance. A feedforward strategy can then be employed by using the estimated disturbance as the measured one to counteract the influence of the disturbance. This concept was then extended to improve the robustness of control systems by estimating the influence of uncertainties in a similar way as external disturbances. Since then, it has been one of my main research areas. Working with other researchers, we have applied the techniques to a wide range of applications, such as guest alleviation for small-scale helicopters and fixed-wing aircrafts. The concept of the disturbance observer and associated control strategy is quite intuitive but difficult to analyze initially. It took many years to be widely recognized and accepted.

Starting in 2005, I developed a strong interest in unmanned aerial vehicles (UAVs) and their applications. With government and industry support, my research in this area covers almost all aspects associated with UAVs, including autopilot, computer vision, situational awareness, decision making, collision avoidance, mission planning, and verification and validation. A key focus of our research is safety. We have developed autonomous functions and contingency management functions to support the operation of large UAVs in the civil airspace, such as autonomous forced landing and autonomous taxiing. The

autonomous system technologies have been extended to areas like precision agriculture and environment monitoring. I also have research interests in driverless cars and advanced driver assistance systems. Through this long journey, I have gradually realized that control is indeed a very important enabling technology, but it is only a small part of a big picture.

Q. What courses do you teach relating to control? Do you have a favorite course?

Wen-Hua: I am only teaching senior undergraduate and postgraduate students, currently courses on flight control systems and avionics systems for our aerospace engineering program. Recently, we also developed a new M.Sc. module in autonomous vehicles. This course is very popular among students. My favorite undergraduate course is the final-year research projects. I am very pleased to see how students gradually build their problem-solving skills, starting from knowing almost nothing about the area when first beginning the project and finally feeling like an expert on the topic in the final presentation. This is quite a rewarding process.

Q. What are some of the most promising opportunities you see in the control field?

Wen-Hua: This is a very interesting question, and no one has a crystal

ball to see the future. I would like to give my view, based on my experience, from two aspects. First, we are facing a number of global challenges including food security, clean water, health care and an aging society, climate changes and environment protection, and energy. Control as a key enabling technology shall and must play its role in addressing these global challenges. We need to explore and understand how control is able to make contributions and develop relevant technologies in this context. Second, computer technology [or, more broadly, information technology (IT)] has a profound impact on our daily lives. It is also playing a key role in driving the development and advancement of other academic disciplines. For the control field to have a promising future, we need to exploit and harness the latest developments in IT and develop new control theories and techniques. MPC is a good example that exploits the available computing power to find optimal control solutions online.

In our research on the cognitive search of airborne chemical and biological release sources, Bayesian inference is combined with path planning for robots and UAVs to decide, at each step, what is the best move to maximize the chance of finding the sources. This informative-based planning and control contributes to intelligent environment monitoring. Another example in our work is precision agriculture or smart farming using autonomous system technologies. UAVs, together with robots and satellites, provide remote-sensing capabilities for enabling crop management and intervention at a variable rate and in a timely manner.

Our current applications include disease (yellow rust for wheat), weeds (blackgrass for cereals), and insects (locusts). For intelligent irrigation management system research, by assessing the water stress level of crops and integrating this with crop growth models, computer-controlled irrigation equipment can apply water at the most suitable time and quantity, which

Profile of Wen-Hua Chen

- *Current position:* autonomous vehicles professor, Loughborough University United Kingdom.
- *Contact information:* Department of Aeronautical and Automotive Engineering, Loughborough University, Leicestershire, LE11 3TU, United Kingdom, w.chen@lboro.ac.uk.
- *IEEE Control Systems Society experience highlights:* member, Technical Committee on Aerospace Control (2010); general chair, IEEE International Conference on Automation and Computing (2014) and Organizing Aerospace Control Workshop (2017).
- *Notable awards:* Fellow, IEEE, Institution of Engineering and Technology, and Institution of Mechanical Engineers; IMechE Charles Sharpe Beecher Prize for the best paper in aerospace (2012).

reduces water waste while maintaining the yield of crops.

Q. You are the author of several books in the control field. What topics do these books cover?

Wen-Hua: Yes, I have been involved in writing and editing a few books in the control field. The most significant

one is *Disturbance Observer Based Control: Methods and Applications*, published by CRC Press in 2014. Together with my coauthors (Shihua Li and Jun Yang), we attempted to produce the first book that systematically described and summarized the concept, theory, design methods, and their applications of the disturbance observer techniques. We

were quite pleased with the book when we completed it. However, as it was prepared as a monograph, I now feel the scope was too specific and narrow. I am considering writing a new book on this topic at the postgraduate level if I manage to find time.

Q. What are some of your interests and activities outside of your professional career?

Wen-Hua: If possible, I like to spend most of my spare time with my family. I still maintain my reading hobby from my university days. I also like walking and visiting different places in the world and exploring local culture and history. I regard this as one of the biggest advantages of being an academic. In my leisure time, although I am not a very good player, I play badminton regularly with my family and friends and really enjoy it.

Q. Thank you for your comments.

Wen-Hua: You are most welcome.