Self-Assessment Letter

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In this self-assessment letter, I give a short summary and self-assessment of the attached documentation. I received a B.S. in Industrial Automation from University of Science and Technology of Beijing, China, in 1985; an M.S. in Automatic Control from Beijing Institute of Technology, China, in 1989; and a Ph.D. in Advanced Controls from Nanyang Technological University, Singapore, in 1998. I joined Utah State University (USU) in 2000 first as a research assistant professor and then, in 2002, a tenure-track assistant professor. I am currently an assistant professor of Electrical and Computer Engineering (ECE) at USU and Director of Center for Self-Organizing and Intelligent Systems (CSOIS). My general teaching and research interests are basic and applied research in dynamic systems and controls. My current research focuses autonomous systems and intelligent control of a team of unmanned ground and aerial vehicles, distributed control systems (MAS-net: mobile actuator-sensor networks), fractional order control and signal processing, and iterative/repetitive/adaptive learning control. I was named the Researcher of the Year for 2006-2007 by the Electrical and Computer Engineering Department.

My current role statement prescribes a 40/50/10 split between teaching, research, and service efforts, respectively. In the remainder of the self-assessment letter, I give a summary of my activities in each of these areas.

Teaching

I was hired in the fall of 2000 by CSOIS to lead the Sensing and Perception Group for autonomous ground mobile robot research while teaching one upper level course per semester. I have taught the following graduate and undergraduate level courses:

- ECE/MAE 6330 Nonlinear and Adaptive Control, Spring 01, 02, 03
- ECE/MAE 7350 Intelligent Control Systems, Fall 2000
- ECE/MAE 7360 Optimal and Robust Control, Fall 01, 03, 04, Spring 07,
- ECE/MAE 7750 Distributed Control System, Spring 02, Spring 05
- ECE6010 Random Processes in Electronic Systems (3 credits, 1 time)
- ECE/MAE5320 Mechatronics (lab intensive course, 4 credits, 5 times)
- ECE3620 Circuits and Signals (3 credits, 2 times)

In addition, I have guided the following Special Topic (ST) or independent study courses:

- ECE6930 ST: Machine Vision in Control & Automation (3 credits,4 times)
- ECE7930 ST: Computational Intelligence (3 credits, 1 time)
- ECE7930 ST: Computational Optimal Control (3 credits, 1 time)
- ECE6930 ST: Advanced Control Designs (3 credits, 1 time)
- PHYX2400 ST: Nanoscience and Technology - Materials Today (National Science Foundation Nanotechnology Undergraduate Education Program – NSF NUE)
- PHYX3500 ST: Nanomechatronics (NSF NUE)

ECE/MAE 6330 Nonlinear and Adaptive Control was first taught by me in 2001 using a new textbook (Khalil 2002). The flexibility in selecting chapters to cover is good and the students liked this course in general, which instills the nonlinear systems thinking and systematic designs addressing the nonlinearities.

ECE/MAE 7360 Robust and Optimal Control is a top level control course that addresses the real issues when the knowledge about the systems to be controlled is uncertain. Contrary to basic controls, robust control is to design a robust controller for a family of plants to meet some optimality requirements under worst case situations. I found this course very important for students majoring in controls. It has been my favorable course with best student evaluations.

In 2002, I redesigned ECE/MAE 7750 Distributed Control System to include sensor networks, networked control systems, distributed parameter system governed by partial differential equations and industrial Distributed

Control Systems (DCS). I have included my own research on mobile actuator and sensor networks into this course to maximize the student's learning performance. This course has a quite unique research flavor that prepares the student to meet the future challenges in this nano-bio-info world.

I created the lab intensive (4 credit) course ECE 5320 Mechatronics as the second control course with an emphasis on synergistic view of computer controlled mechatronic systems. In this course, I have put sensors, actuators, digital control basics, system identification, and digital control designs in an integrated manner accompanied by a series of well-designed labs. In developing the labs, I have chosen the Quanser real time control kit to achieve "rapid prototyping of real time control systems." I found that my industrial experience in Seagate on hard disk drives, an intelligent mechatronics device, is very useful in teaching this course. After several years of development, this mechatronics lab is among the best in the nation.

ECE3620 Circuits and Signals is an Electrical Engineering core course that mainly covers convolution and Laplace transform with emphasis on circuit based differential equation solving. I found this course very challenging but also very rewarding. Transferred students from different institutions using different textbooks with different levels of preparation are a bit hard to synchronize in the beginning. So, I have added numerous help sessions. I find great satisfaction in helping the students pass the hurdle and jump from the technician level to engineer level.

I also guided several on-demand independent study courses that helped the students to better fulfill their Program of Study and better prepare them for their career. In particular, we have been awarded an NSF NUE grant to teach two nanoscience nanotechnology related courses under Special Topic arrangement. It was a good success.

On the student advising side, I have graduated two Ph.D. and nine M.S. students. I have also mentored several undergraduate students. Hyo-Sung Ahn, my first Ph.D. student graduated, has secured a tenure-track faculty position in a research university in Korea (Kwangju Institute of Science and Technology). Part of his Ph.D. dissertation has been published as a research monograph in the prestigious Springer's Communication and Control Engineering Series in 2007. He was also voted as the Outstanding Graduate Research Assistant of the year 2006 by the department faculty. Zhen Song, my second Ph.D. student graduated, is working in Siemens Research Center. Zhen's research platform has won the second prize in the 2005 Crossbow Smart Dust Contest. I have co-authored numerous papers with my graduate students. Two student papers by Hyo-Sung Ahn and Haiyang Chao have been final listed as Best Student Paper Award candidates in 2005 and 2006 IEEE International Conference on Mechatronics and Automation, respectively. One student paper by Zhen Song has won 2006 Sarnoff Symposium third prize best paper and the student paper by William Bourgeous and Shelley Rounds won the Best Student Paper Award from The Third ASME/IEEE International Conference on Mechatronics and Embedded Systems and Applications (MESA07). Currently, I am the major professor for two Ph.D. students, six M.S. students, and I guide six undergraduate researchers.

For my teaching philosophy, I like the fun saying about education: "*Education is what is left when one forgot all he or she has learned.*" It is true that education is the process of shaping the way of thinking. My teaching philosophy is simply "*teaching is always not enough*." I feel that during the teaching, in this information explosion age there are just too many things there and it is impossible to include all of them in my classes. Teaching materials should be dynamically evolving and balancing the teaching materials is an art. My idea is not to overstuff the students but to teach them to learn why, how, where and what to learn. Teaching is to build the "fishing skill" of the students rather than simply feeding the students with the "fish."

Teaching is a process requiring constant innovative ideas as the socio-technological environment involves. Teaching is also a rewarding process where I can learn from the class. Teaching and learning are bi-directionally beneficial. With enthusiasm in teaching, I would like to conclude that "*Teaching is a pleasure.*" Furthermore, teaching helps me to prepare and recruit good students in my research programs. In turn, my research also helps my teaching when I bring in my classroom my research results.

In conclusion, I have a strong passion in teaching and constantly bring my research into the classroom. My student evaluations in average are above the department average. I believe I am a qualified engineering educator constantly seeking teaching excellence.

Research

My current research activities focus on three areas: iterative learning control, fractional calculus for control and signal processing, and mobile actuator and sensor networks. These research areas closely fit in the general area

of “dynamic systems and controls.” Note that control is both science and engineering. Most researchers live in-between control science and control engineering depending on societal needs and funding atmosphere. My contributions in these areas are summarized below.

Iterative Learning Control

My Ph.D. topic was on “Iterative Learning Control” (ILC). The basic idea of ILC is to make use the repeated nature of the operation to improve the control performance from iteration to iteration, just as basketball shooter trains him-/her-self in a repetitive manner. When I joined Seagate for hard disk drive (HDD) servo control development, I was the first to apply the ILC idea in HDD to compensate the repeated run out (RRO). This was awarded two US patents (US6,563,663 and US6,437,936). Now, this idea is a routine practice running on millions of hard disk drives. I am also among the first to apply the ILC idea for chemical batch processes. I have organized many invited sessions in various conferences on ILC, given several tutorial lectures (half day) on ILC and its applications. I am among the top researchers in the world in the field of ILC. Google constantly ranks my link http://www.csois.usu.edu/ilc/ as number one on “Iterative Learning Control”. In http://www.engineeringvillage2.org, I am the number three author on Iterative Learning Control among 1964 records. Research along this line attracted an industry contract in 2004 with 3 months summer salary offered.

Selected Publications (corresponding author)*

[1] YangQuan Chen* and Changyun Wen, “*Iterative Learning Control: Convergence, Robustness and Applications*,” Springer-Verlag, Lecture Notes Series on Control and Information Science, vol. LNCIS-248, 1999, 199 pages, ISBN: 1-85233-190-9.

[2] Hyo-Sung Ahn, Kevin L. Moore*, and YangQuan Chen. “*Iterative Learning Control: Robustness and Monotonic Convergence for Interval Systems*,” Springer-Verlag, Communications and Control Engineering Series, 2007, ISBN: 978-1-84628-846-3. (203 pages).

[3] YangQuan Chen*, Kevin L. Moore, Jie Yu and Tao Zhang. “Iterative Learning Control and Repetitive Control in Hard Disk Drive Industry – A Tutorial,” *International Journal of Adaptive Control and Signal Processing*. (accepted to appear).

[4] Ahn, Hyosung; Chen, YangQuan*; Moore, Kevin. "Iterative learning control: survey and categorization 1998-2004," *IEEE Transactions on Systems, Man, and Cybernetics--Part C: Applications and Reviews*. November issue of 2007, to appear.

[5] Hyo-Sung Ahn, Kevin L. Moore, YangQuan Chen*, “Monotonic Convergent Iterative Learning Controller Design based on Interval Model Conversion,” *IEEE Trans. on Automatic Control*, vol. 51, no. 2. Pages: 366- 371.

[6] Hyo-Sung Ahn, Kevin L. Moore and YangQuan Chen*. “Stability analysis of iterative learning control system with interval uncertainty,” *Automatica*. Vol. 43, 5, pp. 892-902, May, 2007.

Notes: [1] is mostly based on my PhD dissertation with some extensions which is the second research monograph in ILC. [2] is based on part of my first Ph.D. student’s dissertation. [2] is in a very prestigious book series. [3] is based on the Industrial Tutorial session I organized at IEEE Conference on Decision and Control (CDC) in 2006, the top conference in the control field. [4] is a comprehensive literature review offering a good service to the field. [5] and [6] are two recent top journal papers on our contributions to ILC research when considering interval uncertainties in the model. I have graduated one PhD in this research direction.

Fractional Calculus and Fractional Order Control

Many real dynamic systems are better characterized using a non-integer order dynamic model based on fractional calculus or differentiation or integration of non-integer order. Traditional calculus is based on integer order differentiation and integration. The concept of fractional calculus has tremendous potential to change the way we see, model, and control the nature around us. *Denying* fractional derivatives is like saying that zero, fractional, or irrational numbers do not exist. There are numerous research possibilities in controls and signal processing. Google ranks my links on fractional order control and fractional order signal processing on top. In http://www.engineeringvillage2.org, I am the number three author on fractional calculus and number one author on fractional order control. Research along this line has attracted NRC Twinning grant (2003-2005), an NSF SBIR phase-1 subcontract in 2006 in addition to three other internal grants. I have filed a patent on tuning of fractional order controls (US20060265085) in 2006. In terms of impact of my research, I was the first to organize a full day

workshop at 2002 IEEE International Conference on Decision and Control (CDC) which was very well received. The online workshop CD and 316 pages workshop lecture notes have also been well cited. The group I am leading is well recognized as one of the leading groups in the world on fractional calculus and its applications in controls and signal processing. I am also quite well connected in this field. In 2006, I was invited to deliver a plenary lecture at IFAC International Workshop on Fractional Derivative and Applications (FDA2006) in Porto, Portugal where I also received the Achievement Award.

Selected Publications (corresponding author)*

[1] Dingyu Xue, YangQuan Chen* and Derek Atherton. "*Linear Feedback Control – Analysis and Design with Matlab*," SIAM Press, 2007, ISBN: 978-0-898716-38-2. (348 pages) Chapter-8: Fractional-order Controller - An Introduction.

[2] YangQuan Chen*, Tripti Bhaskaran, and Dingyu Xue. "Practical Tuning Rule Development for Fractional Order Proportional and Integral Controllers," *ASME Journal of Computational and Nonlinear Dynamics.* 2008. Accepted to appear.

[3] Nikita Zaveri, Rongtao Sun, Nephi Zufelt, Anhong Zhou*,., YangQuan Chen*. "Evaluation of microbially influenced corrosion with electrochemical noise analysis and signal processing," *Electrochimica Acta* 52 (2007) 5795–5807.

[4] Ahn, Hyosung; Chen, YangQuan*, and Igor Podlubny. "Robust Stability Checking of A Class of Linear Interval Fractional Order System Using Lyapunov Inequality," *Applied Mathematics and Computation*, 187 (2007) 27–34.

[5] YangQuan Chen*, Hyo-Sung Ahn and Dingyu Xue, ``Robust Controllability of Interval Fractional Order Linear Time Invariant Systems,'' *Signal Processing*, Vol. 86 (2006) 2794–2802.

[6] Blas M Vinagre and YangQuan Chen. "*Fractional Calculus Applications in Automatic Control and Robotics*". Lecture Notes Prepared for The Tutorial Workshop at the IEEE International Conference on Decision and Control (CDC), Dec. 9, 2002, Las Vegas, USA. (316 PDF pages).

Notes: [1] is a new style textbook containing for the first time a dedicated chapter on FOC. [2] contains breakthrough results on tuning rule development for first-order plus delay systems. [3] is published in a high impact journal with an innovative fractional order Fourier transform method for data analysis. [4] is a brand new method for robust stability analysis of interval fractional order linear systems. [5] is the first to address the controllability issue of interval fractional order linear systems. [6] is the well received lecture notes. I have graduate 3 MS students in this research direction.

Mobile actuator and sensor networks (MAS-net)

With technology advancement, we are no longer constrained to lumped parameter thinking. In distributed parameter systems, a spatial domain of interest must be considered. Consequently, how to arrange actuators and sensors, possibly mobile and wirelessly connected, in the spatial domain, is an exciting new research. I believe I am responsible for defining this new area of research. It can be thought of as a new level of ground mobile robot research. I called it TOMAS-net (task-oriented mobile actuator and sensor networks), or in plain words, "smart sniffing and spraying problem" (when talking about toxic gas containment and neutralization). My team is among the first in applying Intel's Mote technology. Our platform has won the 2nd place in the Crossbow Smart Dust Contest in 2005. The same framework has won the NSF DDDAS/SEP grant and the IREE supplement grant. In addition, I have won the National Science Foundation Research Education for Undergraduates (REU) site grant on MAS-net for three years (2006-2009). I also organized a full day workshop at IEEE/RSJ IROS2005 in Edmonton, Canada which was well received. Our research in the past five years has now attracted attention from the research community. Recently, we applied the same framework to water related problems using a team of unmanned aerial vehicles (UAV). Currently, this UAV+Water, another version of "smart sniffing and spraying problem" (soil moisture sniffing and irrigator administration), has been supported by Utah Water Research Lab and it is now in the Year-2 funding. I believe, mobile actuator and sensor networks research has a long lasting research potential and impact.

Selected Publications

[1] YangQuan Chen*, Zhongmin Wang and Jinsong Liang. “Optimal Dynamic Actuator Location in Distributed Feedback Control of A Diffusion Process,” *International Journal of Sensor Networks*, Volume 2 - Issue 3/4 – 2007, pp. 169 – 178.
[2] Zhen Song, YangQuan Chen*, JinSong Liang and Dariusz Uci´nski. “Optimal Mobile Sensor Motion Planning Under Nonholonomic Constraints for Parameter Estimation of Distributed Systems,” *Int. J. Intelligent System Tech. and Applications*, Vol. 3, Nos. 3/4, 2007, pp. 277-295.
[3] Haiyang Chao, YangQuan Chen*, and Wei Ren. “A Study of Grouping Effect On Mobile Actuator Sensor Networks for Distributed Feedback Control of Diffusion Process Using Central Voronoi Tessellations,” *International Journal of Intelligent Control and Systems*, Volume 11, Number 3, September 2006, pp. 185-190
[4] Haiyang Chao, YangQuan Chen*, Wei Ren. “Consensus of Information in Distributed Control of a Diffusion Process using Centroidal Voronoi Tessellations”. *Proc. of the IEEE Int. Conf. on Decision and Control*, New Orleans, LA, Dec. 2007. Accepted.
[5] Haiyang Chao, Yongcan Cao and YangQuan Chen*. “Autopilots for Small Fixed-Wing Unmanned Air Vehicles: A Survey”. *Proc. of the 2007 IEEE Int. Conf. on Mechatronics and Automation* (ICMA07), Harbin, China, August 5-9, 2007.
[6] Dariusz Ucinski*, YangQuan Chen. “Sensor Motion Planning in Distributed Parameter Systems Using Turing's Measure of Conditioning”. December 13-15, 2006. San Diego. *Proc. of the IEEE Int. Conference on Decision and Control*, pp. 759 – 764.

We are building up our excellence along this research direction. The progress so far is good. I have graduated one Ph.D. student and four M.S. students in this research direction.

Service

I am active in both campus/community service and professional service. I served as Academic Mentor for the Engineering Theme Housing Program (Vector Floor), jointly created by USU Food and Housing Service and The College of Engineering from 2001-2003. I also served as Chinese Student and Scholar Association (CSSA) Faculty Advisor in 2003, in addition to many other campus service roles. For professional service, I have served in International Program Committee in numerous professional conferences. I have been an Associate Editor in the Conference Editorial Board of IEEE Control Systems Society since 2002. I have been an Associate Editor of ISA Review Board for AACC's American Control Conference since 2004. I am a founding member of the ASME subcommittee of "Fractional Dynamics" in 2003. In particular, in 2007, I served as Program Chair of the ASME/IEEE International Conference on Mechatronics and Embedded Systems Applications (MESA07), and Program Co-Chair for IEEE International Conference on Mechatronics and Automation (ICMA 2007, ICMA 2006). I was invited to serve as “Mechatronics Track Chair” for IEEE International Conference on Industrial Electronics and Applications (ICIEA) in 2007. During the 2006 IEEE Mountain Workshop on Adaptive and Learning Systems, I served as Award Committee Chair.

Overall Assessment

In numbers, I have taught seven different courses plus six different special topic courses at USU; graduated two Ph.D. and nine M.S. students; published fifty-six journal papers since 2002 plus numerous conference papers; attracted research fund of $425,000 external Principal Investigator (PI), $330,000 external co-PI, $354,000 internal PI, plus an additional recent NASA grant of $436,000 as PI. Currently, I am the major professor for two Ph.D. students, five M.S. students, and guiding six undergraduate researchers.

Teaching and research are two great pillars of higher education. When integrated well, these two pillars are complementary in support to each other rather than competing. Research fosters openness toward learning. By conducting research, teachers become ongoing learners that allow them to expand the knowledge base of effective teaching methods and to keep abreast of new information. As a junior faculty, I strive to achieve excellence in both pillars by integrating research and teaching. Overall I feel I have made good progress in both teaching and research to my career in academe.