

A TRIBUTE IN MEMORY OF PROFESSOR XUNJING LI ON HIS SEVENTIETH BIRTHDAY

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Professor Xunjing Li passed away in February, 2003, at age 68, in Shanghai, where he had lived for about half a century, almost equivalent to all his professional life. Professor Li was known to many of his students as “Lao Ban”, which means “Boss” in English. This is not only because of his absolute authority sensed by his students, but most importantly is because of his vision in finding new directions of research, his rigorous attitude towards each and every detail in the research work, and his role as a mentor to many young mathematicians he had fostered. He has been greatly missed by all his students, colleagues, collaborators, especially in the event such as the international conferences on stochastic control, mathematical finance, and/or backward stochastic differential equations, like the one held this year (2005) in Fudan University.

Professor Xunjing Li was born in Qingdao, Shandong Province, China, on June 13, 1935. He came to Shanghai in 1956, at age of 21, as a graduate student in the Department of Mathematics, Fudan University, after receiving a Bachelor degree of Mathematics from Shandong University. He spent three years for his graduate study, under the supervision of the renowned mathematician Professor Jianguo Chen, in the area of approximation theory of functions. He started his teaching and research career in 1959, when he became an assistant professor in the Department of Mathematics, Fudan University. He was promoted to Lecturer in 1962, to Associated Professor in 1980^a, and to Full Professor in 1984. In 1985, he became a nationally appointed Doctoral Supervisor, and was named as a Distinguished

^aFrom 1966 to 1976, China was in the period of “*Cultural Revolution*”. All academic titles in universities were abolished during that period

Professor of Fudan University in 1997. Professor Li retired in 2001.

During the forty-five year span of his professional life, Professor Xunjing Li grew from a student to a researcher and an educator, and made inefaceable contributions to the advances in control theory and related fields in China. He was best known for his works on Maximum Principle for optimal controls of infinite dimensional control systems, and is one of the most prominent pioneers in the area of the optimal control theory of distributed parameter systems in China. Professor Li's another major contribution to the Chinese and the international control community was, arguably, the fact that he almost single-handedly found and fostered a stochastic control group in Fudan University, which has produced a flock of scholars who later become influential players in the area across China, Europe and North America.

Professor Li's research achievements can be chronologically summarized according to the following main periods.

1. 1959—1976. Almost as soon as Professor Li finished his graduate study and started work as an assistant lecturer in the Department of Mathematics of Fudan University, he switched his research direction from Function Theory to Ordinary Differential Equations. This was partly due to a call from the department to expand the academic areas, and as a young faculty member Professor Li enthusiastically answered. Following the leadership of Professor Fulin Jin, Professor Li spent tremendous amount of time in the teaching and research in this new area. In 1962, when he was only 27 years old, he co-authored the text book "*Ordinary Differential Equations*" with Professor Fulin Jin. The book has been widely used as a main text/reference book by researchers and students in China for many years. In the meantime, as a natural extension of the theory of ordinary differential equations, Professor Li began to explore the area of control theory in early 1960's. While working on the subject of absolute stability of (finite dimensional) dynamic systems, he participated in another important service activity to the Chinese control theory community: this time was the translation of the celebrated monograph "*Mathematical Theory of Optimal Processes*" by L. S. Pontryagin et al. In the middle of 1960's, when Professor Li's research activities just started to take off, the whole direction of China took an unfortunate turn. During the ten-year period of 1966-1976, the normal education and scientific research were strongly discouraged and even interrupted due to the "Cultural Revolution". Taking the only opportunity in late 1960's to apply his expertise in optimal control theory, Professor Li turned to industrial and applied mathematics. He participated in several projects associated with Shanghai Petroleum Refinery Factory, as well as Jin-Shan Petroleum Chemical Cooperation. These experiences later became an important factor for his perspectives towards control theory throughout his research.

2. **1977—1987.** The year 1977 marked a resurrection and a new era of Chinese education system, as well as a turning point in Professor Li's research career. Starting from that year, many traditional teaching and research activities began to be restored, including the national college entrance examination, a long tradition in China for universities to enroll freshman students, at both undergraduate and graduate level^b. However, the scar in the scholastic activities and scientific research caused by the ten-year turmoil period was clearly visible, the research results achieved by many scholars like Professor Li but shelved for a decade became a little out-of-date. Inspired by the new spring in the scientific field, he started to ponder over the new germinating points of his research. After a careful survey of articles and evaluating his strength, he decided to attack the infinite dimensional optimal control problems. The first breakthrough came out in 1978, in a joint work with Professor Yunlong Yao, then an assistant professor. For a time optimal control problem of infinite dimensional linear systems, they realized, in general the attainable sets is not necessarily convex (a substantial difference from the finite dimensional case), but they discovered that its closure must be. Such an observation, together with the separation theorem for convex sets in infinite dimensional spaces, lead to a proof of maximum principle of time optimal control for infinite dimensional linear systems. Their work was published in the top journal in China, *Scientia Sinica* ("Science in China"), and was later presented in the 8th International Federation of Automation Conference (IFAC), Kyoto, Japan. While this might be considered usual by today's standard, but back then when China was just opened up, it was indeed a highly recognizable event. The subsequent several years then witnessed a series of research accomplishments by Professor Li and his group, including the second author. The vector-valued measures in the infinite dimensional optimal control theory was investigated in depth, and the Pontryagin's maximum principle was extended to various cases of general semi-linear evolutionary distributed-parameter systems. Among many other results, the one that involves terminal constraints is particularly worth mentioning. It was known that in the finite-dimensional case, the maximum principle requires only the differentiability of the coefficients, provided the the terminal constraint set is closed and convex. But there exist counter-examples showing that this is no longer the case in general for the infinite dimensional systems. As a consequence, seeking the proper conditions under which the maximum principle remains valid became a long-standing challenging problem. In 1985, Li and Yao successfully resolved the problem with rigor and elegance. They proved that, for the general semi-linear evolutionary distributed-parameter systems, if the terminal constraints satisfy the *finite co-dimension condition*, then the maximum principle holds. This result was highly recognized by the international control community, and was later regarded as the foundation of the "Fudan School" research on the infinite-dimensional optimal control theory.

^bBoth authors of this article were the beneficiaries of this new policy, though at different levels.

3. 1987—2001. Since 1985, a group of new researchers, mostly the new generation of graduate students after the class of 1977, started to join Professor Li's research group. By 1988, some new Ph.D's from Europe and US returned to China and became the important new addition. Among others, most notable were the Post-doctor Shige Peng (France) and Associate Professor Jiongmin Yong (USA). In 1989, Professor Li, in collaboration with Jiongmin Yong, further extended the maximum principle to the general semilinear evolutionary distributed systems with mixed initial-terminal constraints, by using Ekeland's Variational Principle and an improved "spike" variational method. This ignited another wave of activities, and a variety of infinite dimensional versions of the maximum principle were knocked down. It is commonly recognized that finite-dimensional optimal control theory has three milestones: the maximum principle by L. S. Pontryagin, the method of dynamic programming by R. Bellman, and the linear quadratic optimal control theory by R. E. Kalman. Professor Li's research covered essentially all the areas, although the main focus in his earlier years was on the representation of the Pontryagin maximum principle in the infinite dimensional spaces. Many of Professor Li's works and thoughts, along with many results obtained by the control theory research group of Fudan University (a.k.a. "Fudan School"), can be found in the book *"Optimal Control Theory for Infinite Dimensional Systems"*, co-authored by Xunjing Li and Jiongmin Yong, and published by Birkhäuser in 1995. The book summarized quite exhaustively the latest results in the optimal control theory of nonlinear, deterministic, infinite dimensional systems up to that point, from the perspectives of the aforementioned three milestones. It was very well commented by researchers in the field of control theory.

Although for the most part of his professional life, Professor Li considered himself a "deterministic person", he was nevertheless in essence the main reason of the existence of several research groups, including the stochastic control group and later the mathematical finance group, in Fudan University. Since 1985, especially after he visited several universities in USA, he had a vision that Fudan had to develop the research direction on stochastic control. He began by organizing a stochastic control seminar, and directing several of his graduate students, including the first author^c, to study and to explore new problems in that area. With Professor Li's cultivation, the scope of the research on stochastic control was quickly expanded to most of the subjects in the field. In his late years, Professor Li personally involved in many research projects on stochastic control theory. Collaborating with Shuping Chen, Ying Hu, Shige Peng, Shanjian Tang, Jionming Yong, Xunyu Zhou, and others, he worked on various problems in linear quadratic control problems, Maximum Principle for stochastic control systems with partial observations, and with jumps. Apart from these works, Professor Li also made important contributions in many other areas such as multi-player differential games, infinite dimensional

^cThe first author later went on to complete his Ph.D dissertation, on singular stochastic control problems, at University of Minnesota.

linear quadratic unbounded optimal control, and optimal control of elliptic partial differential equations.

As a closely related subject to his research, Professor Li also had far-reaching perspectives toward infinite-dimensional dynamical systems and applications, an area that has been rapidly and richly expanding since 1980's. In 1982 and 1983, he invited three leading mathematicians in this area, Professors Jack Hale, George Sell, and Shui-Nee Chow, to visit Fudan University. Inspired by these successful visits and encouraged by Professor Li himself, Xiaobiao Lin (now a professor at the NCSU, Raleigh) and the second author later finished their doctoral dissertations at Brown university and at the University of Minnesota, respectively, on topics of infinite-dimensional dynamical systems and then become active and prolific researchers in this area.

In addition to his mathematical research, Professor Li's life-long pedagogical achievements constitute another highlight of his life. Professor Li supervised four postdoctors, eleven Ph.D students, thirteen Master students, as well as many junior faculty members. Professor Li was famously known of being strict to his students (this in effect earned him the name "Lao Ban", as we mentioned before). In fact, looking back, almost all his former advisees could tell some anecdotes where he or she learned lessons, sometimes embarrassing, from Professor Li. However, this might exactly be one of the main reasons that many of them became successful later on, when they became professors, researchers, supervisors, and principal investigators themselves. As one of the main figures in dynamic system and control theory in Fudan University and in China, Professor Li showed tremendous leadership by not only encouraging young faculty in his research group to boldly explore new areas, but also guiding his graduate students in their studies and investigations in areas unfamiliar to himself. This philosophy of Professor Li was the key for success in many cases with his graduate students. It was because of these efforts that the research directions of the Fudan (control theory) group expanded and developed progressively, from distributed parameter control systems in 1970's and 1980's, to stochastic control theory in 1980's and 1990's, and to mathematical finance throughout the 1990's and continuing through the 2000's. It would not be exaggerating to say that without Professor Li, the Fudan University would not have a control group of a history like what it is seen today.

This year when we cherish the memory of Professor Xunjing Li on his seventieth birthday, we all feel that his adamant scholastic spirit and his rigorous scientific approach have more or less become a part of our own professional life in conducting research and in educating younger generations of graduate students. We are proud to be a part of "Fudan School", and glad to see that the named of the group is being carried on by many more talented and dedicated mathematicians year after year, and hopefully for years to come. We believe that this is what Professor Li would be pleased to see as well.

Acknowledgments

Another important obituary that describes Professor Xunjing Li's role in the development of control theory and related fields in China is the preface (in Chinese) of his collection of articles¹. Our tribute can be considered an adapted version of that article, and we owe our sincere gratitude to the authors of that article—Shuping Chen, Shige Peng, and Jiongmin Yong, for their effort of collecting all the historical information regarding Professor Li's professional life, which is indeed the basis of this tribute.

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