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PERSONAGE IN SCIENCE

Professor G. Leitmann

on for 85th birthday

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This paper presents a biographical sketch and a review of scientific achievements of George Leitmann, who made outstanding contributions in contemporary nonlinear dynamics and systems theory.

1 Introduction

George Leitmann was born in Vienna, Austria on May 24, 1925. He emigrated, with his mother and two grandmothers, to the USA in 1940. Leitmann entered a technical high school in New York from which he graduated in 1943. Immediately after graduation he joined the US army and served in the reconnaissance unit of a Combat Engineer Battalion in France in 1944-45. For his role in the battle for Colmar, Leitmann was awarded the Croix de Guerre avec Palmes. At the end of the war, he was assigned to the Counterintelligence Corps as its youngest special agent and served as an interrogator at the Nuremburg war crimes trial in 1946. After his discharge from military service in 1946, Leitmann began his university education at Columbia University in New York. He received a BA degree in physics in 1949 and an MS degree in physics, with research on secondary electron emission, in 1950. From 1950-57 he worked as a physicist and then as head of aeroballistics at the rocket development center, China Lake, California. During that period he also enrolled in the University of California, Berkeley, from which he received the PhD in engineering science, with a dissertation on the exterior ballistics of high altitude rockets, in 1956. He joined the engineering faculty of the University of California, Berkeley as an Assistant Professor of engineering science in 1957; he was advanced to Associate Professor in 1959 and to Professor in 1963. During his employment at the rocket development center, Leitmann worked on the design and testing of a variety

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of rockets. From the outset in 1950 he was concerned with optimization of rocket trajectories by controlling the thrust magnitude and direction. He had already done research on this problem while preparing his PhD dissertation; he became especially interested in this topic meeting the famous Chinese scientist H.S. Tsien then at the California Institute of Technology. Of Leitmann's many published results in the 1950's and early 1960's, [1]–[6] and Chapter 5 of [A] constitute a sample. They are primarily based on the Calculus of Variations and extensions to allow for inequality constraints, already treated in the 1930's by G.A Bliss at the University of Chicago. To place Leitmann's contributions to rocket trajectory optimization within the extensive body of work in this area, see [7]. After exposure to the calculus of variations and somewhat later to the maximum principle as well as to Bellman's dynamic programming, Leitmann decided to compare various optimization techniques, particularly those employed to address aerospace — related problems; see [A]. In the 1960's, a meeting with Austin Blaquiere revealed that both Blaquiere and Leitmann were seeking an optimization method which is non-variational in contrast to the calculus of variations and the maximum principle, both of which are based on comparison of solutions. Fortuitously, both Blaquire and Leitmann were thinking about a geometric approach; this led to a long period of collaboration and a life-long friendship. In 1955 Leitmann married Nancy Lloyd. They have a son and a daughter as well as three grandchildren.

2 Basic Trends in Leitmann's Research

2.1 A geometric approach to optimal control and dynamic games

The geometric approach to optimal processes, initiated by A. Blaquiere and G. Leitmann [8], [B], Chapter 7 of [C], [9], [J], is not only an alternative avenue to the necessary optimality conditions embodied in the pioneering works of the Pontryagin school, but an investigation of the complex structure of optimal processes. This approach is based on global properties of optimal processes in cost-augmented state space and utilizes local aspects of these global properties to arrive at necessary conditions for optimality. This becomes even more important in dynamic games, initially treated for two-person zero-sum differential games by R. Isaacs. Various aspects of these zero-sum games were investigated at first for both qualitative and quantitative games [10], [11], [D], [E]. Subsequently, these results were extended to non-cooperative many-player games [F]. Many applied problems, especially in OR and economics, were treated via the geometric-approach-based theory, [12]–[15]. Since necessary optimality conditions yield only candidates for optimal solutions, there is considerable interest in sufficient conditions which assure optimality. Especially field type sufficient conditions for optimal control and even more so for dynamic games were inspired by the geometric approach [I], [16]–[18]. On the other hand, the direct sufficiency conditions in [I] can be applied to problems for which classical ones, requiring convexity, respectively concavity, do not apply[1].

2.2 Stabilization of dynamical systems with deterministic uncertainty

There is great interest in stabilizing, in some sense, dynamical system behavior in the presence of uncertainty. The subject has been considered and treated from two points

[1]A. Novak, Applying the Leitmann–Stalford Sufficiency Conditions to Maximization Control Problems with Non-Concave Hamiltonian, 11^{th} Workshop on Optimal Control, Dynamic Games and Nonlinear Systems, Amsterdam May–June, 2010.

of view: the uncertainty is statistical or it is deterministic. It is the latter model to which Leitmann has contributed. His approach appears to have been inspired by his exposure to Lyapunov stability theory on the one hand and to dynamic game theory on the other. Thus he has adopted a "worst case design" approach by allowing for a "game against nature", that is, a qualitative game with uncertainty modeled as a destabilizing opponent [19]–[21]. He soon dropped the game approach in favor of the simpler and more direct Lyapunov one, especially in the case of nonlinear systems. In order to assure continuous feedback control, he replaced the requirement for asymptotic stability by guaranteed ultimate boundedness as well as state feedback by output feedback [22]–[28]. Also of interest he considered the model following [29]. There exists a very large number of papers on applications in engineering, OR, economics, and related areas. A selected sample is the included of Section 3.

2.3 A coordinate transformation-based equivalent problem approach to optimization

Leitmann invoked invariance arguments to obtain the maximum propulsive efficiency of rockets, Chapter 13 of [A]. By the way, this topic had been the subject of many incorrect solutions up to that time, all of which violated required invariance. In 1967 Leitmann proposed a coordinate transformation which results in a problem which is "equivalent" to the originally posed problem and whose optimal solution is obtained directly, that is by simple inspection. He considered this approach for the simplest problem of the calculus of variations [30]. In the late 1990's, Leitmann returned to this idea and extended the method by obtaining results applicable to a wider class of optimization problems, [31]–[34]. Shortly thereafter, D.A. Carlson[2] pointed out a relation of Leitmann's approach to that of Caratheodory in his classic 1935 book on the calculus of variations and partial differential equations. As in the case with Blaquiere in the early 1960's, this led to a lasting collaboration and personal friendship which continues to this day and which has led to many contributions to the subject, [35]–[39], [41]. A relation to Noether's invariance transformations was noted by Torres [40]. And more recently, further aspects of the relation to the work of Caratheodory, in particular the substantial simplification due to the use of Leitmann's regularizing transformations, was noted by Wagener[3].

2.4 Avoidance control

There is ever-growing interest in collision avoidance, whether in the sense of evading a pursuier [42]–[44] or in view of such concerns due to increasing volume of highway and air traffic. To address this type of problem, Leitmann and Skowronski introduced the notion of avoidance control in the 1970's, not from a game–theoretic but rather from a Lyapunov theory point of view [45], [46]. This method has become the primary control scheme for collision avoidance currently in use[4].

[2] D.A. Carlson, An observation on two methods of obtaining solutions to variational problems, J. Optimiz. Theory and Appl., Vol. 115, No. 1, 2002.

[3] F.O.O. Wagener, On the Leitmann equivalent problem approach, J. Optimiz. Theory and Appl., Vol. 142, No. 1, 2009.

[4] D.M. Stipanović, A survey and some new results in avoidance control, 15$^{\text{th}}$ Int. Workshop on Dynamics and Control, eds. J. Rodellar and E. Reithmeier, p. 166f., CIMNE, Barcelona, 2009.

3 Applications-directed Research

While most of Leitmann's research has been and continues to be oriented toward applications, much has been applied to specific problems ranging over a wide array of subjects including some already mentioned in the preceding sections. Here then is a sample of his work dealing with specific problems: Economics [47, 48]; ecology [49]–[51]; earthquake engineering [52]–[54]; fisheries [55]–[57]; flight in wind shear [58]–[61]; robotics [62]–[64]; medical applications [65]–[67]; vibration suppression [68]–[69]; terrorism [70], [71].

4 University Activities

In addition to the professional appointment from 1957–1991, when he became an emeritus, he acted as a consultant to industrial companies and as member of governmental committees as well as University ones. He was the first University ombudsman, acting dean and associate in three areas. Afterwards, he served for four years as chairman of the engineering faculty and is at present associate dean for International Relations and professor in the graduate school.

5 Professional Activities

Leitmann has been on many professional society committees and was the founding president of the Alexander von Humboldt Association of America. He edited the Journal of Mathematical Analysis and Applications for 16 years, and he has served and continues to serve as Associate Editor of four journals and as member of eight editorial boards.

6 Awards

Leitmann is a member of the National Academy of Engineering of the USA and a foreign member of six academies of science or engineering. He received numerous medals and prizes including the Senior Scientist Award as well as the Humboldt and the Heisenberg medals of the Humboldt Foundation. He received the Levy Medal of the Franklin Institute and the Oldenburger Medal of the American Society of Mechanical Engineering. He was given the top awards of the professional societies in his field, the Isaacs Award of the International Society of Dynamic Games and the Bellman Control Heritage Award of the American Automatic Control Council. He is Commander of the Orders of Merit of Germany and of Italy, and he holds three honorary doctorates. Most recently, he was awarded the Medal of Honor of the Universität der Bundeswehr.

7 Public Activities

Leitmann is a keen supporter of the arts. Currently he is Chairman of the Board of the Artship Foundation of San Francisco. He has published his free translation of Bela Balasz' "Mantle of Dreams", Kodansha International, Tokyo. He performs occasionally in plays presented by the university drama club. G. Leitmann has published over 300 books and papers. The bibliography and other information can be seen on www.me.berkeley.edu/faculty/leitmann.

List of Monographs and Books by George Leitmann

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List of Selected Papers by George Leitmann

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