IFAC 60th Anniversary

Summary of actions taken at the 20th IFAC World Congress, Toulouse, July 2017

By Luc Dugard, IFAC 2017 World Congress IPC Vice-Chair, in charge of the History part of the program and Dimitri Peaucelle, IFAC 2017 World Congress General Chair

1. IFAC 60th Anniversary Celebration

IFAC celebrated its 60th anniversary at the 20th IFAC World Congress in July 2017, in Toulouse, France, the country where IFAC was founded in 1957. To mark the 60th anniversary, the IFAC 2017 World Congress program emphasized presentations on the history and the future of a number of theoretical and application areas of automatic control. A part of the Congress Program was therefore dedicated to the History of IFAC and to History of Control in general. The Congress gave the opportunity to submit papers with a special "history paper" label thus allowing to gather such papers in coherent sessions and to proceed with appropriate reviewing of these contributions.

The presentations were structured around two semi-plenary invited history lectures, two panel sessions on the IFAC Story and the History of Automatic Control, five invited history sessions and two invited history open tracks. The Congress also paid a tribute to A. M. Lyapunov who strongly influenced the various developments on the theory of stability.

In the framework of the International Program Committee and of the National Organizing Committee, the IFAC 60th anniversary celebrations were organized by Luc Dugard, Steve Kahne & Vladimir Kucera (chairpersons) and Bernard Grabot & Patrice Remaud (co-chairpersons), under the supervision and guidance of Janan Zaytoon**,** IFAC 2014-2017 President, Dimitri Peaucelle, IFAC 2017 General Chairperson, Denis Dochain and Didier Henrion, IFAC 2017 International Program Committee Chairpersons.

2. Tribute to A. M. Lyapunov

In 2017, the 160th anniversary of Lyapunov's birthday was celebrated. The Lyapunov ideas and methods have had a real impact on the foundation of modern control theory with the notions such as "Lyapunov stability", "Lyapunov function," or "Lyapunov exponent." Also, year 2017 marked 125 years of the outstanding Lyapunov memoir "Obshchaya zadacha ob ustoichivosti dvizheniya" (The General Problem of the Stability of Motion) printed in Russian by the Mathematical Society of Kharkov and 110 years of its French translation. This translation was performed by Edouard Davaux, Marine Engineer at Toulon, and published as « Problème général de la stabilité du mouvement » in *Annales de la Faculté des sciences de l'Université de Toulouse,* 2nd ser., **9** (1907), 203-474, and then was reprinted by Princeton University Press in 1949. Lyapunov reviewed and corrected the French version, introducing some additional material.

The tribute to A. M. Lyapunov was given during an Historical invited Open track (The Legacy of A.M. Lyapunov to Systems and Control Theory. 110 Years of the Toulouse Edition "The General Problem of the Stability of Motion" - II, July 11, 2017) and during the Panel Session on the History of Automatic control (July 12, 2017).

3. Opening ceremony

During the Opening Ceremony July 9, 2017, two artists performed, mastering the stability (of motion) when driving their "vehicle", making thus a nod to the theory of stability of motion.



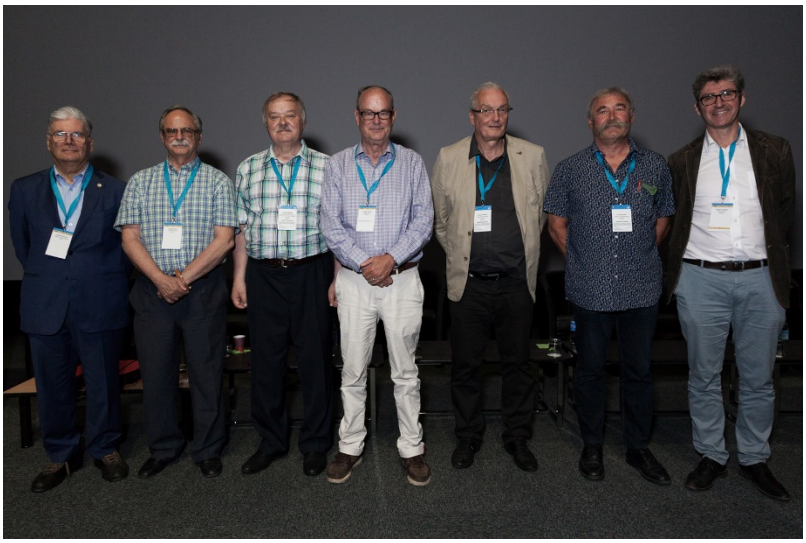
4. Panel session “The IFAC Story” and the associated e-book

An e-book, included in the USB flash discs distributed to all congress attendees, was published by the IFAC History committee on the IFAC history under the supervision of Stephen Kahne. This e-book and the Story of IFAC were presented during a Panel Session (The IFAC Story, July 11, 2017) chaired by Stephen Kahne, with the participation of Pedro Albertos, Vladimir Kucera and Wook Hyun Kwon as panelists. A special release of the e-book in a hard cover box was also offered to President’s dinner guests and to those having attended the History panel sessions.

During this panel session, these four IFAC Past Presidents made brief remarks followed by a moderated discussion with the audience of topics related to the history of IFAC. IFAC has evolved during the past 60 years into a federation including 69 different countries that have from time to time been part of the IFAC community. In 2017, there are 50 National Member Organizations in IFAC’s General Assembly from all parts of the world. The IFAC Story, now available on the IFAC web site, describes this evolution, highlights of which were mentioned during this panel discussion.


5. Panel Session “History of Automatic Control”

A panel session on the “History of Automatic Control”, organized to emphasize some historical aspects of Automatic Control, was presented by six panel members. They developed different points such as: Maxwell as a precursor of system identification and control science; the development of the two main roads in system identification and system identification for control; the impact of results by Lyapunov to the development of control theory; the development of discrete event systems and manufacturing automation; the control influence in aeronautics and aerospace. The panel session was chaired by Luc Dugard. Discussions with the audience followed the panelists’ presentations (Sergio Bittanti, Lennart Ljung, Pavel Pakshin, Manuel Silva, Gérard Morel, and Daniel Alazard). The summaries of the presentations are given hereafter.



The celebrated paper ‘On Governors’, published in the Proceedings of the Royal Society of London in 1869, is one of the first contributions to the analytical study of feedback systems. The author, James Clerk Maxwell (1831, 1879), is therefore hailed as one of the early control scholars. However, during the final years of his studies at Cambridge University, **Maxwell** made another equally important system theoretic contribution: his essay entitled ‘On the stability of motion of Saturn’s rings’ (1859). In this essay, he adopted a peculiar approach to the comprehension of the nature of the rings, which anticipated today’s techniques of model identification.

The area of **System Identification** is as old as IFAC, and IFAC has played an important role in building up the area, primarily through the long running series of IFAC Symposia. The area has developed along two main routes, both originating in the 1960's: The statistical Maximum Likelihood/Prediction error approach and the system oriented realization approach. The relevance of identification to control applications has been an important focus, both in terms of model structures and experiment design.

Impact of Results by **Lyapunov** to the Development of **Control Theory.** It is impossible to imagine modern control theory without such notions as "Lyapunov stability", "Lyapunov function" or "Lyapunov exponent". The significance of the Lyapunov function method in development of the control theory is discussed. A deep connection between Lyapunov function and other universal functions such as Bellman function in optimal control theory and storage function in dissipativity theory is indicated. The role of the Lyapunov equations and inequalities in the problem of control design, based on modern linear matrix inequalities (LMI) technique, is also discussed. Some difficult and unsolved problems are noted.

Discrete Event Systems (DES) starts to develop according to several partially disjoint but complementary threads, all of them dealing for a long while with the modeling, analysis and synthesis

of human-made systems. For example, manufacturing, transportation or communication systems. Furthermore, applications to population dynamics, epidemiology or biochemistry, for example, are becoming of increased importance. Roughly speaking, DES theory and engineering was constituted at the confluence of Automatic Control, Computer Science & Engineering, and Operations Research.

Manufacturing Automation faced the challenging Factory of the Future over the forty past years characterizing two complementary goals relating to large-scale system-of-systems control, resulting in the well-known centralized/hierarchical architecture of Computer Integrated Manufacturing and to some promising distributed/heterarchical architecture for Intelligent Manufacturing Systems.

The gained systemic knowledge should contribute to regenerate the control scientific corpus required to tackle at the right holistic scaling factor the open-ended changes pushed by the technosphere-centered paradigm of Internet for Things as well as the biosphere-centered paradigm of regenerating sustainability.

Aerospace engineering has been always a key application field to illustrate the historical developments and major contributions from automatic control theory. The Kalman filter for aerospace vehicles state estimation or Pontryagin's minimum principle for optimal guidance are well-known examples. From the automatic control viewpoint, a specific feature of Aerospace applications is the use of knowledge-model based approaches rather than "black-box" approaches. Since control algorithms available today support increasingly complex and detailed models, the trend today is to include the models of various subsystems in the design model in order to optimize the overall performance of the system. This was confirmed very recently with the increasing activity on UAVs: the systemic approach becomes more and more multi-disciplinary.

6. Invited Historical Sessions

Thirty-three “history” papers were submitted, mainly within Invited Sessions (IS) and Open Invited Tracks (OIT). This resulted in six invited historical sessions and/or open tracks, leading overall to nine slots for these sessions, which included many survey papers. The main idea was to set up special sessions related to the history and evolution of a number of important areas in Automatic Control. This idea met a great success with more proposals than expected and a very good attendance to the sessions.

Session MoA13
A Tribute to Rudolf E. Kalman
Chair: Kucera Vladimir Co-chair: Yamamoto Yutaka
Organizer: Kucera Vladimir

- Rudolf E. Kalman: Life and Works by Kucera Vladimir (Czech Tech. Univ. in Prague)
- The Influence of R. E. Kalman - State Space Theory, Realization, and Sampled-Data Systems, by Yamamoto Yutaka (Kyoto Univ)
- Kalman's Expanding Influence in the Econometrics Discipline, by Wilcox Bruce and Hamano Fumio (California State Univ. at Long Beach)
- Professor R. E. Kalman - Reflections on His Way of Thinking, by Khargonekar Pramod (Univ. of California, Irvine)
- Rudolf E. Kalman's Quest for Algebraic Characterizations of Positivity, by Georgiou Tryphon T. (Univ. of Minnesota)
- Rudolf E. Kalman and the Riccati Equation (I) by Kucera Vladimir (Czech Tech. Univ. in Prague)

Sessions MoM13 and MoP13
History of Discrete Event Systems
Chair: Silva Manuel Co-chair: Lafortune Stéphane
Organizer: Silva Manuel

- Modeling, Analysis and Control of Discrete Event Systems: A Petri Net Perspective, Giua Alessandro (Aix-Marseille Univ. France / Univ. of Cagliari, Italy) & Silva Manuel (Univ. De Zaragoza)
- Max-Plus Algebra and Discrete Event Systems, Komenda Jan (Acad. of Sciences of Czech Republic), Lahaye Sébastien, Boimond Jean-Louis (Univ. Angers, France) & van den Boom Ton J. J. (Delft Univ. of Tech)
- Supervisory Control of Discrete-Event Systems: A Brief History -- 1980-2015, Wonham W. Murray (Univ. of Toronto), Cai Kai (Osaka City Univ) & Rudie, Karen (Queen's Univ)
- From Diagnosability to Opacity: A Brief History of Diagnosability or Lack Thereof, Lafortune Stephane (Univ. of Michigan) & Lin Feng (Wayne State Univ)
- Perturbation Analysis: A Framework for Data-Driven Control and Optimization of Discrete Event and Hybrid Systems, Wardi Yorai (Georgia Inst. of Tech), Cassandras Christos G. (Boston Univ) & Cao Xi-Ren (Shanghai Jiao Tong Univ)
- From Discrete Event Simulation to Discrete Event Specified Systems (DEVS), Zeigler Bernard (Univ. of Arizona) & Muzy Alexandre (CNRS)

Sessions TuA11, TuM13 and WeA11

The Legacy of A.M. Lyapunov to Systems and Control Theory.
110 Years of the Toulouse Edition "The General Problem of the Stability of Motion"

Chair: Pakshin Pavel Co-chair: Panteley Elena
Organizers: Kucera Vladimir, Panteley Elena, Pakshina Natalia

- Early Days of the Absolute Stability Theory in Saint Petersburg (Leningrad): Lurie, Rosenwasser, Yakubovich, Fradkov Alexander L. & Lipkovich Mikhail (Saint Petersburg State Univ)
- Yakubovich's Method of Recurrent Objective Inequalities and Its Application in Adaptive Control and Robotics, Gusev Sergei V. & Bondarko Vladimir A. (St. Petersburg State Univ)
- Three Approaches to the Proof of Kalman-Yakubovich-Popov Lemma, Gusev Sergei V. (St. Petersburg State Univ)
- Stability Analysis of 2D Roesser Systems Via Vector Lyapunov Functions, Pakshin Pavel, Emelianova Julia (Arzamas Pol. Inst. of R.E. Alekseev NSTU), Galkowski Krzysztof (Univ. of Zielona Gora) & Rogers Eric (Univ. of Southampton)
- Two Lyapunov Methods in Nonlinear State Estimation Via Finite Capacity Communication Channels, Matveev Alexey S. (St.Petersburg Univ) & Pogromsky A. Yu. (Eindhoven Univ. of Tech)
- Pass Profile Exponential and Asymptotic Stability of Nonlinear Repetitive Processes, Pakshin Pavel, Emelianova Julia, Emelianov Mikhail (Arzamas Pol. Inst. of R.E. Alekseev NSTU), Galkowski Krzysztof (Univ. of Zielona Gora) & Rogers Eric (Univ. of Southampton)
- Aleksandr Lyapunov: Remembered by His Contemporaries, Pakshina Natalia (Arzamas Pol. Inst. of R.E. Alekseev NSTU)
- Stability, As Told by Its Developers, Loria Antonio (CNRS) & Panteley Elena V. (Cnrs, Itmo)
- Scientific School of Vladimir Yakubovich in the 20th Century, Fradkov Alexander L. (Russian Acad. of Sciences)
- What Types of Functions May Be the Perron Function of Diagonal Discrete Linear Time-Varying Systems?, Babiarz Artur (Faculty of Automatic Control, Electronics and Computer Science), Czornik Adam (Faculty of Automatic Control, Electronics and Computer Science), Konyukh, Alexander (Belarus State Ec. Univ) & Niezabitowski Michal (Silesian Univ. of Tech. Faculty of Automatic Control)
- The Stability Postulate of N. G. Cetaev and the Augmented Model Validation, Rasvan Vladimir (Univ. of Craiova)
- Lyapunov Functions: An Optimization Theory Perspective, Polyak Boris T. & Shcherbakov, P.S. (Moscow Inst. of Control Sciences)

- On the Influence of Small Perturbations on the Senior Lyapunov Exponent of the Discrete Time-Varying System, Babiarz Artur (Faculty of Automatic Control, Electronics and Computer Science), Barabanov Evgenij (Inst. of Mathematics of National Acad. of Sciences of Bela), Czornik Adam (Faculty of Automatic Control, Electronics and Computer Science), Niezabitowski Michal (Silesian Univ. of Tech. Faculty of Automatic Control) & Vaidzelevich Aliaksei (Inst. of Mathematics of National Acad. of Sciences of Bela)
- Constructive Analysis of Control System Stability, Osinenko Pavel, Devadze Grigory, Streif Stefan (Tech. Univ. Chemnitz)
- Application of the Localization Method to Stability Analysis and Construction of Lyapunov Functions, Krishchenko Alexander & Golubev Alexey (Bauman Moscow State Tech. Univ)

Session TuA13

History of the Control of Distributed Parameter Systems

Chair: Meurer Thomas Co-chair: Dochain Denis

Organizers: Meurer Thomas, Dochain Denis

- On Fattorini's Paper: ``Boundary Control Systems'', Zwart Hans (Univ. of Twente)
- Time-Domain and Frequency Domain Approaches to LQ-Optimal Control of Infinite-Dimensional Systems, Winkin Joseph J. (Univ. of Namur)
- Stabilization of Partial Differential Equations: The Importance of the Nonlinearities, Coron Jean-Michel (Univ. Pierre et Marie Curie)
- Taking a Step Back: A Brief History of PDE Backstepping, Vazquez Rafael (Univ. De Sevilla) & Krstic Miroslav (Univ. of California at San Diego)
- Some Perspectives in PDE Control, Meurer Thomas (Christian-Albrechts-Univ. Kiel)

Session TuP13

History of Automatic Control in Aerospace Engineering

Chair: Alazard Daniel Co-chair: Nebylov Alexander

Organizers: Alazard Daniel, Nebylov Alexander

- Attitude and Orbit Control Systems of Russian Communication, Navigation and Geodesic Satellites: History, Present and Future, Testoyedov Nikolay, Rayevsky Valentine (ISS Res. JSC), Somov Yevgeny (Samara State Tech. Univ), Titov Gennady & Yakimov Yevgeny (Res. ISS JSC)
- From GOCE to NGGM: Automatic Control Breakthroughs for European Future Gravity Missions, Bacchetta Andrea (Thales Alenia Space), Colangelo Luigi, Canuto Enrico (Pol. Di Torino), Dionisio Sabrina (Thales Alenia Space), Massotti Luca (Esa – Estec), Novara Carlo (Pol. Di Torino), Parisch Manlio (Thales Alenia Space) & Silvestrin Pierluigi (European Space Agency)
- Development Stages and Prospects of Flight Control and Navigation Complexes for Aircraft, Nebylov, Alexander (State Univ. of Aerospace Inst), Tikhomirov Mikhail (Saint Petersburg State Univ. of Aerospace Inst) & Benzerrouk Hamza (IIAAT of SUAI St Petersburg)
- Attitude and Active Payload Control: The H-Infinity Revolution, Pittet Christelle, Mignot Jean & Viaud Frederick (CNES)
- Modern Control Theory and Real-World Aerospace Applications: I Love You, nor Do I?, Zolghadri Ali (Bordeaux Univ)
- The Airbus A320: A Story about Fly-By-Wire Pioneering, Chatrenet Dominique (Retired from AIRBUS)

Session WeP09

300 Years Developments for an Essential Tool in Control System Theory: The Riccati Equations

Chair: Bittanti Sergio Co-chair: Colaneri Patrizio

Organizers: Jungers Marc, Colaneri Patrizio, Bittanti Sergio

- Historical Perspectives of the Riccati Equations, Jungers Marc (CNRS - Univ. De Lorraine)

- Riccati Equations in Nash and Stackelberg Differential and Dynamic Games, Basar Tamer & Moon Jun (Univ. of Illinois at Urbana-Champaign)
- On the Generalized Algebraic Riccati Equations, Ferrante Augusto (Univ. of Padova) & Ntogramatzidis Lorenzo (Curtin Univ)
- A Survey of Riccati Equation Results in Negative Imaginary Systems Theory and Quantum Control Theory, Petersen Ian R (The Australian National Univ)
- On the Stabilizing Solution of Periodic Riccati Differential Equations Related to a Class of Stochastic Linear Quadratic Differential Game, Dragan Vasile (Romanian Acad of Sciences), Aberkane Samir (CRAN, Univ. De Lorraine), Ivanov Ivan Ganchev (Sofia Univ) & Popa Ioan-Lucian ("1 Decembrie 1918" Univ. of Alba Iulia)

7. Semi-Plenary sessions

Two semi-plenary sessions were organized on the key steps in the history of feedback control and on a global perspective on a historical survey and on emerging challenges of manufacturing automation modeling and control.

"Historical Survey and Emerging Challenges of Manufacturing Automation Modeling and Control – A Global Perspective"

by Carlos Eduardo Pereira, Co-authors: Shimon Nof and Gérard Morel

Manufacturing and logistics are fundamental to civilization progress since ancient times. They have been and still serve as important engines of economic, social, cultural and environmental health and sustainability, both locally and globally. Automatic control of manufacturing and logistics has also played a valuable role in this progress. A major dual challenge in manufacturing and logistics systems has always been the need to address simultaneously the multidisciplinary systemic control of technical, human, and natural variables, and overcoming conflicts and emergencies to control safety, resilience and sustainability responsibilities. The purpose of this presentation is to survey historically and with global perspective, with illustrations and case studies the key developments in the automatic control of manufacturing and logistics, and the emerging challenges. Overall, as in many areas, automatic control of manufacturing and logistics has evolved with the developments of human scientific knowledge and education, social organization, and computing and communication advances. In general, the purpose of the automatic control has always been to support the well-being of humans and societies. Past challenges included separation and imprecision of machines and processes, due to reliance on simpler machines, instruments and sensors, and little or no feedback; lack of flexibility, networking, and integration; and reliance mostly on manual supervision of machines and factories.

“Some key steps in the history of feedback control”

by Jean-Michel Coron

Important key steps in the history of feedback control are briefly presented. These key steps include classical and less classical mechanical feedback controllers, the holy grail of the isochronous controller, Maxwell's paper on controller, the Routh stability criterion, the notion of asymptotic stability, and some classical results in "modern control".

8. Continuation and conclusion

The plenaries and the panel sessions have been video recorded and are available on the IFAC YouTube channel.

Congress attendees were invited during fall 2017 to fill a post congress survey. 551 persons answered. One of the questions concerned the historical sessions. It received 387 responses (70,2% of the survey participants). This high response rate as well as the fact that 76% of those who responded expressed their positive appreciation about the history sessions (see the following pie chart), indicate that these sessions have been attractive and interesting for many colleagues.