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Editorial

Automatic Control and System Theory and Advanced Applications—Volume 2

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The aim of the Special Issue on Automatic Control and System Theory and Advanced Applications, the second volume of a previous paper selection, is to emphasize the role of new inventions in the area of automatic control applications. The current literature outlines the following scenario: research is focused on achieving advanced implementation of control techniques based on data analysis and defining optimization algorithms for highly advanced distributed networks devoted to large-scale infrastructure control implementation. Indeed, the practical control applications are limited to particular systems and selected topics of industrial relevance, such as power electronics and automotive. The two Special Issues, therefore, summarize the latest results that took a potentially important place in the aforementioned scenario.

The hope is that these contributions will stimulate other researchers to contribute to the Inventions journal with novel results regarding innovative automatic control and industrial automation devices.

The term *invention* indicates the act and the process of inventing and, therefore, the power of realizing something that does not exist. Today, the term is underestimated. Moreover, especially in engineering, revolutions occur when inventions are created. In automatic control, where each process is different from another, even if a general theory for designing controllers does exist, the efforts are oriented to analyze specific conditions. Only inventions in automatic control engineering can lead really innovative and high-performance apparatuses assuming a revolutionary role [1].

The continuously evolving social demands, such as the need for green energy sources, sustainability, and circular economy, constitute the reference signals for novel automatic control approaches. Under this perspective, inventions and innovation work concurrently to allow the definition of novel control techniques, as in the feedback loops schematically represented in Figure 1.

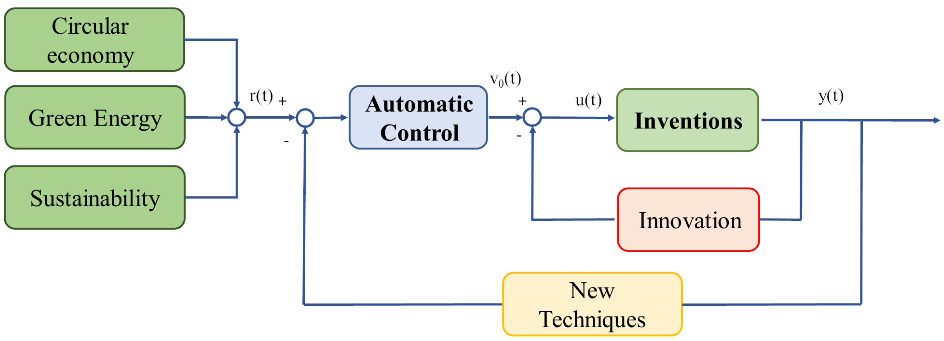

Figure 1. Schematic representation of the feedback loops around inventions and automatic control to cope with emerging social demands.

This Editorial is organized as follows: The contributions collected in the Special Issue are first emphasized in the context of the current literature to offer the readers a complete

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scenario of the actual state of the art in each field in which inventions and automatic control theory are merged.

The core of the six papers collected in the Special Issue is the green electrical energy production, the sustainable applications of automatic control, embedded control systems, sensors/actuators, and signal processing devices designed by CAD techniques.

In the paper by Tien and Tsai [2], the authors approach the optimization of energy in ice-storage air conditioning systems. The adopted strategy is used to produce ice when air conditioning is not useful and to reuse ice to condition air in the phase when climate conditions require it. It represents a smart strategy to save and plan energy for costs and optimize environmental conditions. It requires an accurate and practical optimization algorithm. After formalizing the problem and approaching a practical model, the authors adopted a global algorithm based on the ant colony optimization strategy. The obtained results are compared with the least-square optimization search. It clearly shows the benefit of the proposed solution. The contribution shows how control of innovative energy plants requires advanced optimization strategies and is useful in optimizing costs; this can be achieved using ad hoc methods based on the bio-optimization paradigm. Many simulations and performing trends are shown. Even if the results are referred to a specific application, the strategy could be applied in different energy temperature control processes.

Interestingly, the trend of using ant colony-based optimization strategies is strongly increasing in automatic control applications. In [3], the problem of controlling the torque in switched reluctance motor drives is approached by incorporating ant colony optimization in the design of the control system. This solution allows for higher control performance, especially in terms of accuracy, even in strict constraints, since optimal switching angles are determined, leading to efficient torque tracking in the considered experimental setups. A similar approach can be found in [4], while the problem of cruise speed control of operational aircraft and path planning of mobile robots is also addressed using ant colony in [5,6].

The basic idea in [2] is recovering energy produced in excess. The very same idea is spreading in many automatic control-related papers. An example is the papers by Li et al. [7] and Yan et al. [8], where an intelligent control system [9] is presented to improve the power supply system of this class of vessels in order to recycle cold energy produced in liquefied natural gas (LNG) carriers [10]. Since the problem of energy recovery has gained a strong interest in recent years [11], it has also been studied in a wide range of different applications, as in hydraulic systems, like excavators [12] or hydraulic cylinders [13], to reuse potential energy, thus reducing pollutants, or for improving active suspensions performances [14].

The contribution [15] by Petrochenkov et al. addresses the optimization of oil pumps in severe behavioral conditions. The control strategy proposed by the authors is based on efficient process control principles based on energy consumption. This paper discusses the problem accurately, and the authors show how an accurate knowledge of the process allows one to write the appropriate equations that relate pump characteristics, fluid dynamics, electrical cables, transformers, and control actions in order to obtain a steady-state behavior that is proved to be accurate for the proposed aims. More results about the efficiency of the system are shown. In the general discussion, various critical points are also outlined. Even though it does not discuss the system's dynamic behavior, this paper provides the foundation for the development of intelligent cluster control in subterranean pump installations. The contribution focuses on a few specific points in a truly understudied class of systems.

Subterranean pumps, in fact, only recently gained the attention of control researchers. In particular, the control of these devices is oriented towards optimizing power consumption by adopting strategies based on neural predictors [16,17]. Another key aspect of subterranean pumps is the avoidance of cavitation [18], the formation of gas bubbles in a fluid flow due to pressure changes. Cavitation is determined by numerous factors, including the shape of the streamlined distribution blades [19], which can be opportunely modeled and controlled. The current literature also addresses the problem of controlling pump dynamics in hydraulic driving systems [20], where long transient times may lead to erratic shifting of the power gearbox. The solution proposed in [20] is based on joining a backpropagation neural network system with statechart logic control [21].

The optimal mechanical design of some innovative electromechanical devices, like axial pumps, helps their control. Moreover, further remarks on the global control system must be made when further innovative equipment like non-contact bearing supports are used. Innovation calls for inventions. This is the case considered in the contribution [22] by Nguyen et al., where the invention of a canned motor conical active magnetic bearing-supported structure for a pump device was presented, including a fractional order controller with robustness characteristics. The complete design of both the mechanical and the electromechanical parts is proposed to obtain the definition of a non-integer order compensator. This study is accurately performed thanks to accurate multi-material modeling. Simulation results are appealing and will be the starting point for further real-time control implementations.

Active magnetic bearing systems are gaining strong interest given their groundbreaking application in motors and pumps [23] and when using unconventional solutions based on superconductivity and biomedical devices [24]. The current research is mainly devoted to solutions to mitigate failure risk: in [25], a machine learning algorithm is considered for predicting failures based on the acoustic characteristics of the system. At the same time, a fuzzy logic robust controller is designed [26] to optimize the high-speed performance of an active magnetic bearing motor. An approach based on multi-objective control is presented in [27] for preserving the performance even in the presence of faults. Innovative control strategies for active magnetic bearing devices can also be found in [28–30], where adaptive H-infinity control is adopted for improving speed tracking in the presence of uncertainties [28]. Swarm-based optimization is used to self-tune a PID controller, improving the transient performance [29], and hybrid repetitive control is considered to mitigate harmonic vibrations [30]. This class of systems represents a solid test bench for a wide plethora of automatic control strategies. It is worth mentioning a novel structure for active magnetic bearing that has been recently proposed for satellite attitude control applications [31]: it is based on a homopolar design, thus allowing for both radial and axial suspension forces, leading to an overall device simplification, also in terms of the necessary control systems.

The invention of smart barriers to internal flooding is proposed in the timely contribution by Muñoz-Caballero et al. [32]. This study regards the occurrence of fluxes of water due to floods. The authors correctly emphasize the reported invention with data analysis and the recent weather world conditions leading to sudden floods. The smart barrier allows the water flow to be diverted in the best direction, avoiding a complete flood in the area; this can be carried out thanks to the coupling of smart sensors, actuators, and a control strategy that can be implemented using a low-cost microcontroller network. The automatic platform that controls a set of PLCs is integrated with a software platform that enhances the human–machine control strategy. Moreover, the control system can be handled using a smartphone. The authors include a complete comparison with other similar inventions. The presented work shows how practical problems induce new inventions and that inventions can be appealing thanks to new technologies, even at low costs.

Without nature-based solutions [33], flood barriers are fundamental in minimizing the effects of sudden and heavy water fluxes. A paradigmatic example of a flood barrier is the MoSE system implemented in Venice, Italy, to avoid sea level increases, which lead to inundating the city streets, whose use can be partially reduced to guarantee maritime traffic [34]. The smart barrier system presented in [32] is not a unique solution in this direction. The use of an internet-of-things (IoT) based solution [35] is also described in [36], where a commercial device integrated with a communication network environment is described. The solution is reliable and at a limited cost, allowing the identification of smart barrier control to avoid floods in complex land profiles. However, controlling floods is linked to a series of technological problems that must be considered. An example is the effect of the vibrations induced by flood on the barrier gates, which reduced their dynamical operations: in [37], a combined data-driven and finite elements approach to model this phenomenon is discussed. Automatic control solutions are often linked with new inventions. In the case of flood barriers, kinetic umbrellas are novel devices used to control the barrier action in the presence of highly dangerous situations [38]. They are peculiar devices with a geometry suitable to sustain heavy surge-induced coastal inundation. The peculiarity is that they can adapt their shape; thus, they become very promising in adaptive control strategies [39].

The invention of a new class of thermoelectric generators leads to the use of innovative control schemes and electronic equipment. The paper [40] by Qasim et al. stresses, in particular, this opportunity, remarking on the general principles that led to this Editorial. The Seebeck effect [41] leads to the thermoelectric generator [42]. Moreover, each class of semiconductor has a specific performance. The thermic supply of the considered device is furnished thanks to heat exchange. The control strategy is based on a fuzzy logic device whose tuning can be successfully performed thanks to the particular use of the generator. Moreover, coupled with this innovative device, new DC/DC converters are used. The results are also encouraging regarding the system's time response from a dynamic point of view. Moreover, such a system can be integrated into a renewable multi-energy system network, including solar panels.

The paper [40] deals with engineering problems condensing several inventions and innovative solutions. The automatic control strategy adopted relies on fuzzy control, a topic of emerging interest in control theory, especially in thermoelectric devices [43]. Fuzzy logic [44] is a cornerstone of artificial intelligence as it introduced a computational paradigm based on fuzzy concepts instead of absolute classifications. It has been applied in several fields, especially in modeling [45] and control [46] of complex environments. Moreover, the main subject discussed in [40], i.e., the active use of Seebeck cells, is gaining a strong interest and renewed attention to their modeling [47,48]. In particular, the possibility to adopt them in more complex environments where continuous maximum power point tracking is necessary [49] and especially useful in low-voltage, high-power distribution networks where different thermoelectric generators are included [50,51]. Finally, it is worth mentioning that the devices envisaged in [40] can also be supplied by microfluidic networks [52], making them high-performing for low-power applications. The research of microfluidic devices and their realization is cutting edge as it exploits innovative materials [53] and manufacturing processes [54,55].

The contribution by Manin et al. [56] includes an advanced new study based on the Kalman filter for the state-space variable reconstruction in a stochastic system. Even if the topic is well studied, the authors invented a new strategy for data handling, using a data-fusion approach in a certain sense. Inventions, in this case, mean proposing new calculation paradigms. The invention's success is due to the real application; this is performed by the authors considering the numerical solution for the adaptive assessment of navigation parameters for an autonomous vehicle when high precision is needed despite noisy measurement conditions. The extensive simulation results prove the suitability of the invention.

The Kalman filter is one of the main topics in modern control theory as it represents the optimal observer when inaccuracies and noise in measurements are unavoidable. It joins prediction capabilities with state estimation and filtering. A comprehensive review of the topic, including the most recent advancements, can be found in [57]. The literature on this topic now addresses the problem of improving filter performance in the presence of unavoidable noise sources. In navigation systems, measurement noise is detrimental and should be properly addressed without increasing costs. In [58], a frequency domain analysis is used to improve the accuracy and rapidity of the Kalman filter, resulting in a high-performing navigation system for autonomous underwater vehicles. Adaptivity of the variables statistics estimation is exploited in the solution proposed in [59], where the resulting Kalman filter guarantees practical advantages in carrier-based aircraft navigation systems. Data fusion for improving the capability of classifying features in complex data is adopted in [60], where a Kalman filter is proposed to achieve the feature-level fusion of diverse signals acquired from a hybrid piezoelectric–fiber optic sensor network. The system aims to automatically detect and quantify damages on aircraft, and the proposed solution strongly improves classic approach capabilities. Different approaches to improve Kalman filter estimation in noisy environments are based either on dynamic mode decomposition [61] or model predictive control [62]. Recently, two extensions of the Kalman filter have been gaining particular attention: The unscented Kalman filter [63] and the tensor Kalman filter [64]. The first case refers to introducing a deterministic selection of the sampling points by exploiting the unscented transform, which allows the accurate representation of the mean and covariance of Gaussian random variables, thus obtaining a more reliable estimation. The second case uses matrix algebra relations to generalize all the data structures involved in the classic Kalman filter to the multidimensional tensor domain. Tensor Kalman filters, thus, compress the information in the presence of large data sets.

A recent result collected in the Special Issue concerns green energy production optimization. The paper by Stoyanov et al. [65] discusses a novel method to control the blade position of a vertical-axis wind generator. The method is based on identifying the relationship between the blades' position and motor rotation, thus providing reliable information to achieve automatic control. In this case, the invention relies on both the device and the control method, as the authors propose equipment to identify the relation in real time in the presence of different wind conditions.

In the era of renewable energy sources, wind generators are essential. Under this perspective, the paper [65] is timely and stands out in the current literature. The research directions are multiple, ranging from the miniaturization of wind generators for their use in single buildings [66] or for public services like street lights [67] to the detailed analysis of the geometrical features of the blades to maximize performance [68]. A review of the vertical-axis wind generator configurations can be found in [69], where the main problems of the available technologies are highlighted. As concerns the active control of wind generator performance by shaping the blades of the turbine, it starts from accurate simulations [70], which allows for strategies based on intelligent control aimed at fixing specific angles of attack [71] or blade pitching [72].

Recently, in the *Inventions* journal, further impressive contributions related to the field of this Special Issue have appeared. Readers are recommended to refer to the following list of additional contributions:

- In Duca et al., *Event-Based PID Control of a Flexible Manufacturing Process, Inventions*, 7(4), 86, 2022, the control problem arising in manufacturing processes is discussed. In these cases, the information necessary to design the control action often does not come at regular intervals; therefore, an event-based control action is usually adopted. The solution proposed by the authors is based on an event-based PID controller tested on a conveyor transportation system. The event-based technique allows the PID controller to adapt the information flow from the field, thus ensuring an efficient, reliable, and timely control action. Numerical and experimental results are discussed, showing that the proposed approach improves the system's performance and assessing the possibility of adopting it in further complex scenarios;
- Simion et al., *Mobile Visual Servoing Based Control of a Complex Autonomous System Assisting a Manufacturing Technology on a Mechatronics Line, Inventions* 7(3), 47, 2022, and in the companion paper by Ionescu et al., *Communication and Control of an Assembly, Disassembly and Repair Flexible Manufacturing Technology on a Mechatronics Line Assisted by an Autonomous Robotic System, Inventions*, 7(2), 43, 2002, the invention of a modeling and control environment devoted to complex autonomous systems is the main focus. The environment includes a mechatronic line for manufacturing purposes. An accurate mathematical analysis of the control system, the precise design of the environment, its realization, and testing are reported, providing interesting results and showing the

effectiveness of the invented solution. The companion paper addresses the control and communication problems connected to the invented environment, analyzing the robustness of the control system in the presence of noise and uncertainties.

- Heidari et al., *Design of a Research Laboratory Drive System for a Synchronous Reluctance Motor for Vector Control and Performance Analysis, Inventions*, 6(4), 64, 2022, proposes the realization of a novel synchronous reluctance motor. The paper discusses in detail the control problems linked with the proposed solution and the control applications of the motor. In particular, the realized motor is controlled by adopting a vector control approach, and the test setup is conceived to allow a complete characterization of motor performance in terms of speed and torque. It should be noted that the test setup also allows for real-time validation.
- Schmitt et al., *Incorporating Human Preferences in Decision Making for Dynamic Multi-Objective Optimization in Model Predictive Control, Inventions*, 7(3), 46, 2022, proposes another automatic control-related invention where an automated decision-making procedure incorporating human preferences is discussed developing an emergent application in model predictive control scenarios.
- Moutsopoulou et al., *Robust Control and Active Vibration Suppression in Dynamics of Smart Systems, Inventions*, 8(1), 47, 2023, discusses a smart device based on piezoelectric materials and especially its control for suppressing active vibrations, which decrease the device performance. The control is based on an H_∞ controller, which exploits vibration control strategies.

The advanced control theory [73] is now fundamental in the area of innovation and inventions, in particular, the control of green energy power plants and advanced equipment based on new materials, aiming to get robust and reliable systems. Therefore, we remark that the traditional principles of control, in the era of artificial intelligence strategies, are fundamental to establishing innovative perspectives with resonance also in the field of inventions; this means looking at mathematical methods for control strategies not only as a traditional background but as a motor of novel inventions and innovations.

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