Guest editorial: event-based control and optimization

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Moving beyond the mere observation of complex behaviors to the synthesis of intelligent and networked systems is a long standing dream, which only in recent years has presented fruitful experimental and theoretical investigations ranging in areas from intelligent manufacturing systems to energy-saving buildings, from smart power grid to networked water resources, from environmental systems to financial engineering, and from social networks to cyber-physical systems etc. The reasons for the recent success are diverse and spans over technological advances enabling large-scale information acquisitions, new computing devices and principles provided by embedded software and cloud computing, and the development of novel system architectures and integrations.

Event-based control and optimization focuses on the efficient and timely execution of sensing, actuation, and decision-making in large-scale systems. The growing literature in this area is creating the awareness that in order to capitalize on the rapidly advancing technologies in application domains, there is need for the development of novel modelling and implementation methodologies as well as new analytical and computational tools. In particular, effective event-based methodologies should be feasible with current and emerging information acquisition, transformation, and processing technologies, and should be appropriately tuned to practical systems. To achieve this goal, the field needs to develop thorough system-theoretical analysis and design tools for event-based control and optimization, where new models for asynchronous and aperiodic communication and computing are integrated into the control system.

The purpose of this special issue is to further stimulate such investigations in event-based control and optimization by gathering samples of ongoing research. The collection of results

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will give the control and system engineering community a broad overview of the state of art in the area.

There are seven papers in this special issue. The first one is on “A Tutorial on Event-Based Optimization - A New Optimization Framework” (doi:[10.1007/s10626-013-0170-6](https://doi.org/10.1007/s10626-013-0170-6)). In many practical systems, the control or decision making is triggered by certain events. The performance optimization of such systems is generally different from the traditional optimization approaches, such as Markov decision processes or dynamic programming. The goal of this tutorial is to introduce, in an intuitive manner, a new optimization framework called event-based optimization. This framework has a wide applicability to aforementioned systems. With performance potential as building blocks, two intuitive optimization algorithms are developed to solve the event-based optimization problem. The optimization algorithms are proposed based on an intuitive principle, and theoretical justifications are given with a performance sensitivity based approach. Finally, a few practical examples are provided to demonstrate the effectiveness of the event-based optimization framework.

The second paper is on “Event-Based Optimization of Admission Control in Open Queueing Networks” (doi:[10.1007/s10626-013-0167-1](https://doi.org/10.1007/s10626-013-0167-1)). Here a controller makes decision only at the epoch when an event of customer arrival happens. Every customer in the network obtains a fixed reward for each service completion and pays a cost with a fixed rate during its sojourn time. The controller observes only the number of total customers in the network. Based on the property of closed-form solutions of Jackson networks, it is proven that the system performance is monotonic with respect to the admission probabilities and the optimal control policy has a threshold form.

The third paper is on “A Bi-Level Approach for the Design of Event-Triggered Control Systems over a Shared Network” (doi:[10.1007/s10626-012-0156-9](https://doi.org/10.1007/s10626-012-0156-9)). An efficient usage of available resources is a substantial requirement for the successful design of networked control systems. Recent results indicate major benefits of event-based control compared to conventional designs, when resources such as communication, energy, and computation are sparse. This paper considers multiple entities of heterogeneous control systems whose feedback loops are coupled through a common communication medium. The design of the decentralized event-triggering control system is formulated as an average-cost problem that aims at the minimization of a social cost criterion. A state aggregation technique is used to develop a bi-level design method, which divides into a local average-cost problem within every subsystem and a global resource allocation problem assigning optimal transmission rates. Stability conditions are derived that guarantee stochastic stability of the aggregate system. Under these conditions, it is shown that the design approach is asymptotically optimal as the number of subsystems increases.

The fourth paper is on “Actuator Saturation and Anti-Windup Compensation in Event-Triggered Control” (doi:[10.1007/s10626-012-0151-1](https://doi.org/10.1007/s10626-012-0151-1)). Event-triggered control aims at reducing the communication load over the feedback link in networked control systems by sending information only if certain event conditions, which guarantee a desired control performance, are satisfied. This paper investigates the consequences of actuator saturation on the behavior of the event-triggered control loop in terms of its stability and information exchange. Stability properties are derived using linear matrix inequalities which show how the stability of the event-triggered control loop depends on the event threshold. Moreover, it is shown that a lower bound on the minimum inter-event time exists for the considered event-triggered control system. As actuator saturation might severely degrade the performance of the event-triggered closed-loop system, the scheme is extended by incorporating an anti-windup mechanism in order to overcome this problem. The results are illustrated by simulations and experiments.

The fifth paper is on “Minimum Attention Control for Linear Systems” (doi:[10.1007/s10626-012-0155-x](https://doi.org/10.1007/s10626-012-0155-x)). The attention is interpreted as the inverse of the interexecution time. By choosing an extended control Lyapunov function to be an ∞ -norm-based function, the minimum attention control problem can be formulated as a linear program which can be solved efficiently online. A technique to construct such suitable control Lyapunov functions is presented. The theory is illustrated using a numerical example, which shows that minimum attention control outperforms an alternative “attention-aware” control law available in the literature.

The sixth paper is on “Stabilizing Bit-Rates in Networked Control Systems with Decentralized Event-Triggered communication” (doi:[10.1007/s10626-013-0169-z](https://doi.org/10.1007/s10626-013-0169-z)). Decentralized event-triggered networked control systems in the presence of quantization and delays are studied. Some potential issues in decentralized event-triggered design are pointed out and the authors propose an alternative event-triggering mechanism with a linear-affine threshold. It is shown that the new threshold avoids infinitely fast data transmission. Conditions on the quantizer and communication channel are derived to guarantee stability of the resulting decentralized event-triggered control system. Based on these conditions, stabilizing bit-rates are provided.

The seventh paper is on “Weakly Coupled Event-Triggered Output Feedback System in Wireless Networked Control Systems” (doi:[10.1007/s10626-013-0165-3](https://doi.org/10.1007/s10626-013-0165-3)). This paper examines event-triggered output feedback control when there are separate links between the sensor-to-controller and controller-to-actuator. The proposed triggering events rely only on local information, so the transmissions from the sensor and controller subsystems are not necessarily synchronized. This is an advantage over recently proposed event-triggered control schemes. The paper presents an upper bound on the optimal cost attained by the closed-loop system. Simulation results demonstrate that transmissions between sensors and controller subsystems are not tightly synchronized.

These seven papers cover a wide range of recent results on event-based control and optimization. We believe that the papers are appealing to the experts in the field as well as to those who wish a snapshot of the current research developments.

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