Technical Committee on System Identification and Adaptive Control

The IEEE Control Systems Society (CSS) Technical Committee on System Identification and Adaptive Control (TC-SIAC) is a *community* of professionals and researchers whose main activity is the development of innovative theoretical and technological solutions in the scientific areas of system identification and adaptive control. On the one hand, the system identification domain includes all aspects of data-based modeling and learning (ranging from methodological developments, to computational issues, to practical real-world applications). Important tasks such as model selection, experiment design, and model validation are also addressed. On the other hand, the world of adaptive control concerns all methods and technologies that enable feedback control systems to comply with time-varying environments or system changes like different operating conditions or aging.

The two disciplines share one key feature: *the use of data for control* to devise accurate models of modern complex systems and improve the effectiveness and robustness of nonlinear and time-varying controllers. In the current "big data" era, the research from this community is therefore of paramount importance to provide the right tools to address modern autonomous systems and increasingly challenging control problems.

It is undeniable that system identification and adaptive control are strongly related to traditional statistics, econometrics, and machine learning.

OBJECTIVES

The main goals of TC-SIAC are the following:

- » create opportunities for technical discussions among TC members, with a specific focus on emerging research needs and directions
- » foster the promotion of new initiatives and research interactions among members
- » disseminate relevant information about TC activities inside and outside the CSS (for example, industrial people and students) via an up-to-date website (http://system-identification.ieeecss.org) gathering the list of main events and initiatives of the community as well as recent educational material.

STATUS

TC-SIAC has held regular meetings during every past American Control Conference (ACC) and Conference on Decision and Control (CDC). Given the importance of the fields in modern automation, TC-SIAC is constantly increasing its membership and currently counts *87 CSS active members* at all levels of IEEE membership. The interaction between our TC members and other control communities, such as the International Federation of Automatic Control (IFAC), is very strong, as witnessed by the involvement of several TC members in IFAC TC 1.1. (Modeling, Identification, and Signal Processing) and by their editorial roles with major IFAC journals.

ACTIVITIES

Since the last report for *IEEE Control Systems* dedicated to the TC-SIAC technical activities in June 2019, the efficiency and vitality of TC-SIAC members have been highlighted by the regular organization of invited sessions, tutorials, and workshops (for example, more than 30 sessions have been sponsored by TC-SIAC) in major control-oriented conferences, such as the ACC, European Control Conference, and CDC. In addition, a number of special issues have been promoted in world-leading journals, such as *IEEE Transactions on Control Systems Technology*, *International Journal of Robust and Nonlinear Control*, and *IET Control Theory and Application*, to name a few. The topics proposed for the special issues range from theoretical subjects (such as the modeling and control of hybrid systems) to modern promising applications for system identification and adaptive control (such as biomedical systems or neuroscience). Finally, TC-SIAC members are very active in the development of benchmark case studies and software (including a number of Matlab toolboxes, such as the well-known *System Identification Toolbox*2 to disseminate

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the obtained scientific results to a wide audience.

RECENT RESEARCH

Due to space limits, it would be impossible to report a summary of all of the research activities implemented by TC members. Therefore, as an example, we discuss here one interesting case study showing how system identification and adaptive control may have a significant industrial (but also economic and societal) impact. In Figure 1(a), a schematic representation of a *walking piezo-stepper actuator* is given. These actuators are used, for instance, in high-precision motion stages for electron microscopy. The walking behavior enables an

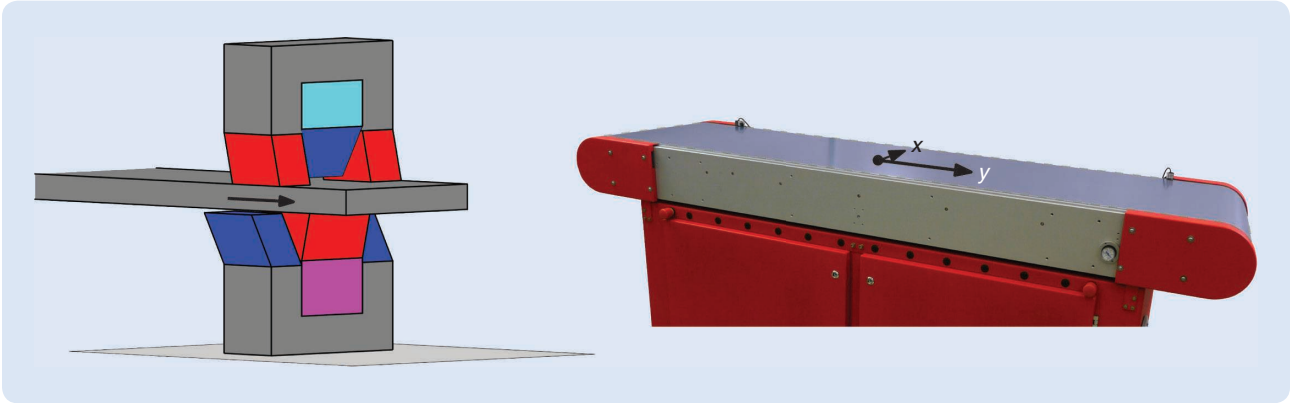

FIGURE 1 The schematics of a walking piezo-stepper actuator and a generic substrate carrier.

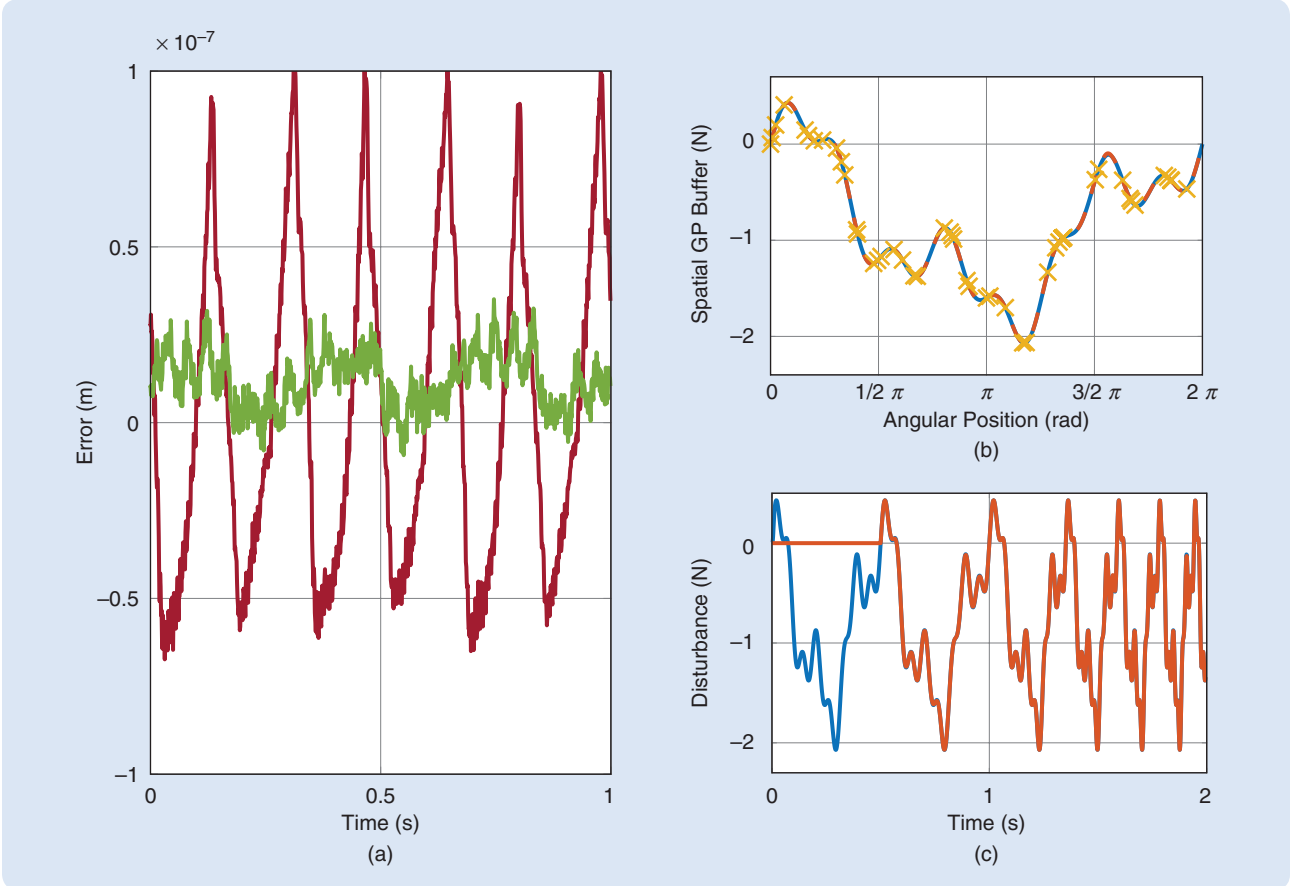

FIGURE 2 The experimental results of position disturbance compensation using innovative learning control showing (a) error, (b) force disturbance, and (c) force disturbance in the time domain. These results were obtained by Leontine Aarnoudse, Noud Mooren, Nard Strijbosch, Paul Tacx, Gert Witvoet, and Tom Oomen. Industrial collaborators from CCM-Sioux (specifically, Lennart Blanken) and Thermo Fisher Scientific (specifically, Edwin Verschueren) are gratefully acknowledged as well as I-mech (ECSEL-2016-1 under grant agreement 737453) and NWO VIDI project number 15698.

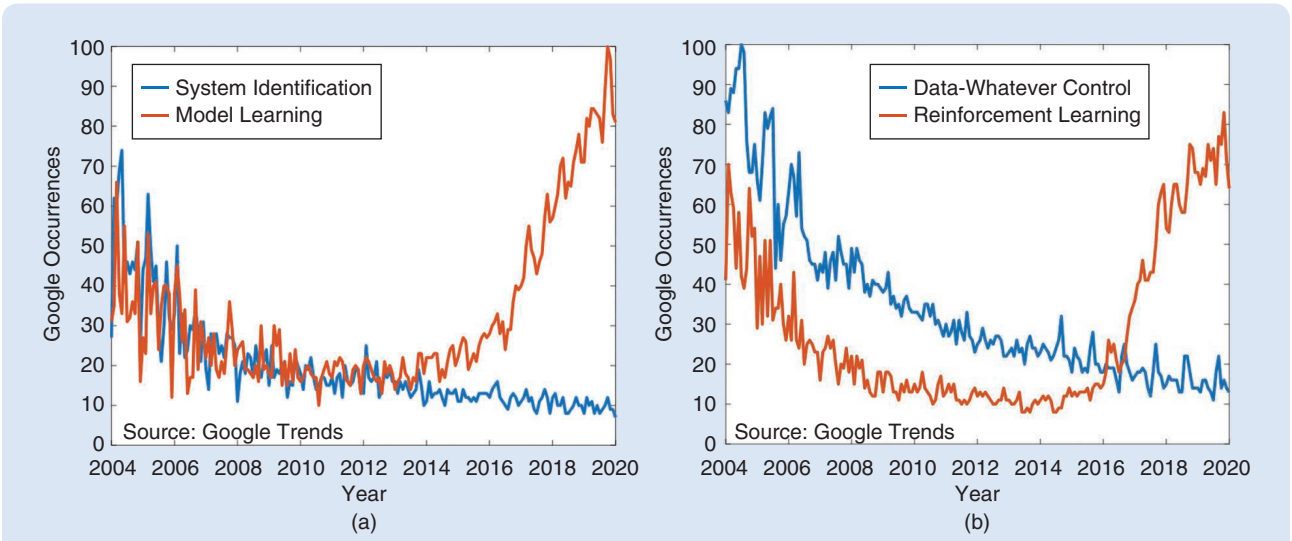

FIGURE 3 Different trends of web searches for the normalized occurrences of the keywords of (a) system identification and (b) adaptive/data-based control as compared to their counterparts in machine learning. (Data source: Google Trends, January 2020).

infinite stroke yet also introduces a disturbance that is periodic in the spatial position domain.

In Figure 1(b), a generic substrate carrier consisting of a belt system is depicted. These belt systems are used at different speeds, for example, in the paper-handling systems of large-volume printer systems. Imperfections in the rollers of this type of system lead to disturbances that are periodic in the spatial domain, and it is well known that disturbances that reproduce in the position domain are a key challenge in industrial applications.

However, the performance obtained by traditional control tools can be outperformed by *learning control* algorithms that *identify* the disturbance directly in the position domain. As an example, Figure 2(a) shows some experimental results of the walking piezo-stepper actuator with a new commutation-angle iterative learning control proposed by the Control Systems Technology Group at TU Eindhoven. In the plot, it is evident that the error without compensation (red line) is significantly larger than the error obtained using commutation-angle learning compensation (green line).

A typical force disturbance in the belt system is also presented in Figure 2(b). The employed learning algorithm exploits the data points (x) that are nonequidistant in the spatial domain and uses these to identify a Gaussian process that represents the periodic position domain disturbance. In Figure 2(c), the disturbance is presented in the time domain (blue line), together with the compensating feedforward (red line). After one full period, the compensation coincides with the disturbance.

A MAJOR CHALLENGE

In the golden age of artificial intelligence and machine learning, researchers and scientists outside our community have also started to use some of our methods and technologies, showing they may be key to solving open problems in different disciplines. However (as clearly shown in Figure 3), it is a fact that while machine learning tools are widely researched and available, there is less awareness of the opportunities offered by our disciplines.

On the one hand, it is undeniable that system identification and adaptive control are strongly related to traditional statistics, econometrics, and machine learning. Nonetheless, they also present profound differences, linked to the context in which they were developed and more than 60 years of successful research and applications in the most diverse fields. A new, very critical challenge for our TC is to find the right way to *spread* our experience and expertise in the industry, in the various scientific communities, and among the new generations of researchers. We have to do it by trying to constructively integrate into the other communities that address the use of data for the creation of knowledge and the progress of engineering, while, at the same time, preserving our identity and our peculiarities.

To achieve our goals, we welcome all interested IEEE CSS members to join. TC-SIAC is particularly interested in involving young, brilliant students and people from industry. Please visit the TC-SIAC website for more detailed information about members and initiatives and send me an email (simone.formentin@polimi.it) to take an active part in our activities.

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