Carlo Regazzoni and Ioannis Pitas

Perspectives in Autonomous Systems Research

Today, many devices (e.g., cars and other vehicles) we operate for various tasks (e.g., to go from place A to place B) are changing: in the past, they were characterized by a body and control actuators that allowed us to perform these tasks. These days, they are not simply passive recipients of our instructions; rather, they have become proactive tools performing the assigned task (or parts of it) by making autonomous decisions based on signals from their sensors.

Therefore, more of these devices can be classified as *autonomous systems*. The level of autonomous decision making can be device dependent but, in every case, involves efficient multimodal signal processing capabilities. Such devices become our agents and have to relate multisensorial data representations to their actions and to the action context. Such a context includes the target of the agent's task, i.e., the action motivation and the user, in cases in which the task is only partially automated.

What is our role as signal processing researchers in autonomous systems research? For many years, our community has developed theories and methods to obtain optimal representations of received/observed heterogeneous signals. Optimality concepts often have been expressed at the signal level, as the signal representation was just a filtered version of the signal itself; in other cases, we had to provide optimal discrete variables or labels as signal processing output. Segmentation of video sequences or speech can be such examples. Some of us are used to working up to the semantic signal analysis level by providing semantic labels to signal segments and associating a meaning to such labels. This moves toward pattern recognition, which, for many of us, is just a mapping of signals to discrete variable domains or label sets. When signal processing is used within an autonomous system, the optimization functional changes again. Here, the optimality is often related to the fact that signals are processed within the agent perception–action cycle aiming at agent decision making for reaching an optimal dynamic equilibrium with the environment and the agent's user.

Autonomous cars, drones, robots, cognitive radios and radars, and intelligent buildings (and much more to come) will be the agents for which we have to provide solutions. Video, acoustic, tactile, and radio signals will be just some of the sensorial signals that should be processed by an agent in real time, for example,

- to interpret the external situation in which it operates
- to relate a situation to its internal state, by observing it with other proprioceptive sensors, so that it becomes self-aware
- to use representations to help its own control blocks to drive its actuators
- to be able to explain at subsymbolic and symbolic levels the reasons for its own choices (see Figure 1).

Over the last decade, researchers have been proposing and investigating computing systems with advanced levels of autonomy to manage the ever-increasing requirements in complexity. An autonomous system is an artificial system able to perform a certain number of tasks with a high degree of autonomy. Many real-world systems frequently experience nonstationary conditions (i.e., unknown situations) due to uncertain interactions with the environment (including human agents) and users, failures, or structural changes. Autonomous systems aim at building up behavior rules over time by learning, through interactions with the environment with complex perception–action cycles, to deal with environment changes and uncertainties.

A fully autonomous system can

- gain information about the environment
- work for an extended period without human intervention
- move either all or part of itself throughout its operating environment without human assistance
- avoid situations that are harmful to people, property, or itself unless those are part of its design specifications.

An autonomous system may also learn or gain new knowledge, such as adjusting for new methods of accomplishing its tasks or adapting to changing surroundings. From an industrial point of view, autonomous systems have exhibited impressive growth in the last decade, notably in autonomous cars, robots, and drones.

Signal processing plays an important role in the perception–action cycle of autonomous systems.

- In autonomous system perception, signal analysis is important for any

(continued on page 146)

Digital Object Identifier 10.1109/MSP.2019.2925436
Date of publication: 9 September 2019

 (continued from page 148)

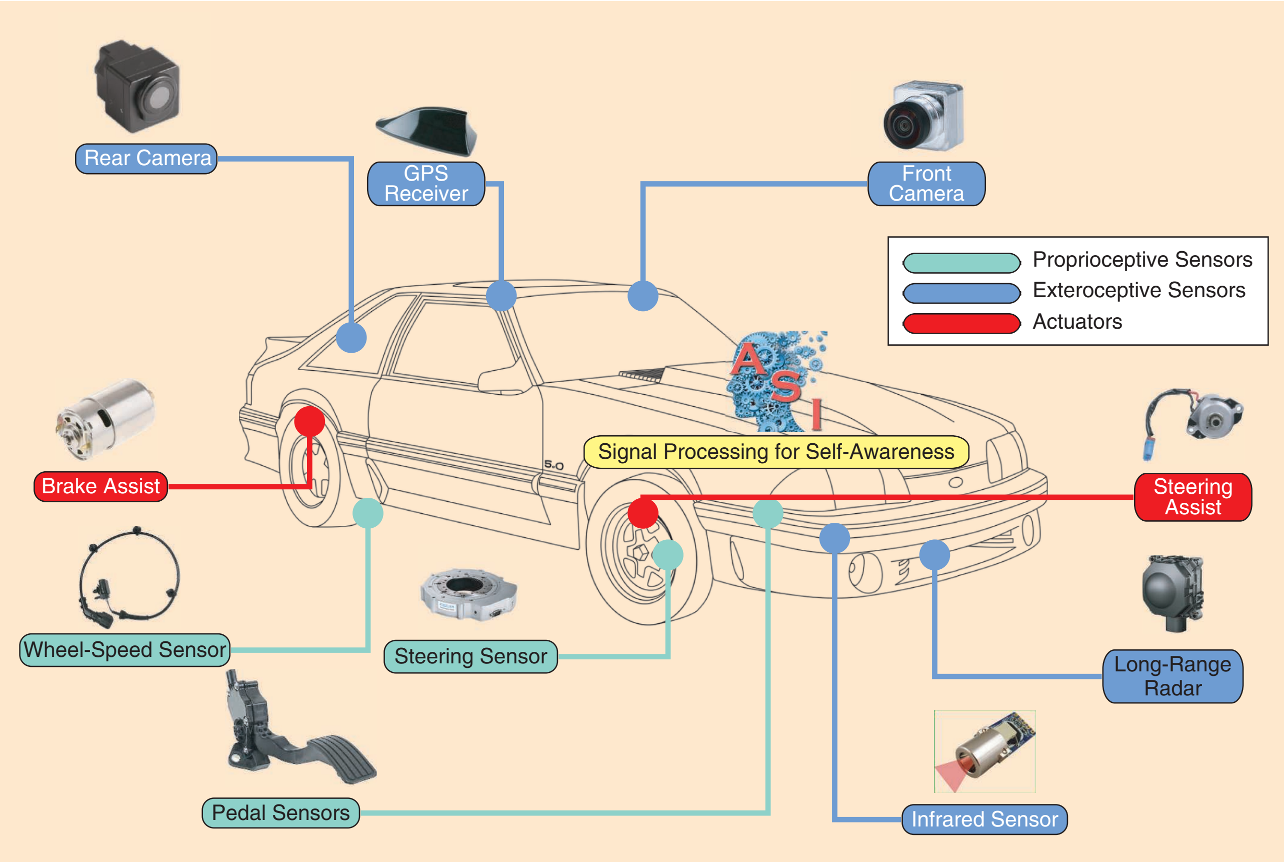

FIGURE 1. An architecture for a self-aware autonomous system. The autonomous vehicle observes the surrounding environment with exteroceptive sensors (blue) and its internal state with proprioceptive sensors (green). It translates its autonomous decisions into actions through actuators (red). The self-awareness core is able to forecast the next state of the environment and of the system itself to detect anomalies and execute the derived actions.

perception modalities, e.g., visual, sonar/ultrasound, laser, or radio/GPS.

- In autonomous system communications, signal (e.g., video) compression, transmission, and error resilience are very important aspects.
- In autonomous system action, adaptive signal processing can play an important role in command and control.

The IEEE Signal Processing Society (SPS) recognized the immensity of the challenges ahead and the research potential and launched the Autonomous Systems Initiative (ASI) during the 2018 IEEE International Conference on Image Processing. From a scientific point of view, ASI can cover the following areas:

- perception
- sensor-information processing
- mission planning and control
- machine learning for perception and control
- robust, secure mobile communications
- embedded systems
- security
- societal issues, e.g., data protection and privacy.

From an industrial/sectorial point of view, it can cover autonomous systems operating in any environment, whether on land, underwater, in the air, underground, or in space. More specifically, this includes

- autonomous cars
- autonomous robotic systems
- marine, underwater vessels
- drones and unmanned aircraft.

ASI is expected to draw significant interest within the SPS constituency but also in the wider scientific community and related industries. To this end, it will cooperate with all relevant SPS technical committees, which will have representatives in ASI. The creation of SPS megatrend ASI will boost SPS involvement in this important and expanding area and allow interaction with other IEEE Societies. Furthermore, it will allow interfacing with other related scientific communities and industrial bodies.

In the last year, ASI has established its bylaws and built an organizational structure (steering committee, members, and associate members). The ASI website (https://ieeeasi.signalprocessingsociety.org/) and a Google docs drive have been created and populated, where a wealth of various ASI activities (special issues, special sessions, tutorials, and workshops) are detailed. Any interested engineer or scientist is welcome to join as an ASI member, associate member, or volunteer by following the procedures described on the ASI website and to contribute to ASI activities.

Proposals on ASI-related activities (e.g., courses, special sessions/issues, workshops, or competitions) for synergies within SPS, IEEE Societies, and other scientific communities and relevant industrial bodies are welcome from anyone who can send an email to ASI Chair Prof. Ioannis Pitas and/or ASI Vice Chair Prof. Carlo Regazzoni.

Authors

Carlo Regazzoni (carlo.regazzoni@unige.it) received his M.S. and Ph.D. degrees from the University of Genova, Italy, in 1987 and 1992, respectively. Currently, he is a professor at the Polytechnic School of the University of Genova, Italy. He has been involved in research on signal and video processing and data fusion since 1988. His current research interests are cognitive dynamic systems, adaptive and self-aware data fusion, machine learning, software, and cognitive radio. He is one of the pioneering researchers in intelligent video surveillance. In 1998, he created the IEEE International Conference on Advanced Video and Signal-Based Surveillance. He is author or coauthor of more than 100 journal papers and 400 conference papers and book chapters (his Google Scholar h-index is 40). He has served within the IEEE Signal Processing Society in various positions including vice president-Conferences (2015–2017). He is currently vice chair of the IEEE Autonomous Systems Initiative. He is a Senior Member of the IEEE.

Ioannis Pitas (pitas@csd.auth.gr) received his diploma and Ph.D. degree in electrical engineering, both from the Aristotle University of Thessaloniki, Greece, where, since 1994, he has been a professor in the Department of Informatics. He has published more than 1,090 papers, contributed to 50 books in his areas of interest, and edited or (co)authored another 11 books. He has also been member of the program committee of many scientific conferences and workshops, an associate editor or coeditor of nine international journals, and the general/technical chair of four international conferences. He participated in 69 R&D projects, primarily funded by the European Union. He has more than 29,000 citations to his work, and his h-index is 79+ (Google Scholar). He leads the big European H2020 R&D project MULTIDRONE and is the chair of the IEEE Autonomous Systems Initiative. He is a Fellow of the IEEE and EURASIP as well as an IEEE Distinguished Lecturer.

SP

SP FORUM

(continued from page 137)

of Technology, Limassol, and his M.S. and Ph.D. degrees in electrical and computer engineering from West Virginia University, Morgantown. He is a professor in the School of Electrical, Computer, and Energy Engineering at Arizona State University, Tempe, where he also directs the Sensor Signal and Information Processing (SenSIP) center and founded the SenSIP industry consortium. He has served as an associate editor of *IEEE Transactions on Signal Processing* and as general cochair of ICASSP 99. He is a corecipient of the 2002 IEEE Donald G. Fink Paper Prize Award. His research interests are in the areas of adaptive signal processing, speech processing, machine learning, and sensor systems. He is a Fellow of the IEEE.

Mónica F. Bugallo (monica.bugallo@stonybrook.edu) received her B.S., M.S., and Ph.D. degrees in computer science and engineering from the University of A Coruña, Spain. She is a full professor of electrical and computer engineering and the faculty director of the Women in Science and Engineering program at Stony Brook University, New York. Her research interests are in the field of statistical signal processing, with emphasis on the theory of Monte Carlo methods and their application to different disciplines including biomedicine, sensor networks, and finance. She has authored and coauthored two book chapters and more than 150 journal papers and refereed conference articles. She is a Senior Member of the IEEE.

References

[1] W. Bajwa, “On ‘flipping’ a large signal processing class [SP Education],” *IEEE Signal Process. Mag.*, vol. 34, no. 4, pp. 158–170, 2017.

[2] A. V. Oppenheim, “One plus one could equal three (and other favorite cliches),” *IEEE Signal Process. Mag.*, vol. 23, no. 6, pp. 10–12, 2006.

[3] S. K. Mitra, “Reminiscences of a department chair,” *IEEE Signal Process. Mag.*, vol. 23, no. 3, pp. 10–13, 2006.

[4] Responsible Metrics, “The metric tide.” [Online]. Available: https://responsiblemetrics.org/the-metric-tide/

SP