Perspectives in Autonomous Systems research

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Nowadays, many devices (e.g., cars, other vehicles) we were used to operate for various tasks (e.g., go from place A to place B) are becoming different: in the past, they were characterized by a body and control actuators that allowed us to perform this task. Nowadays, they are not only passive recipients of our instructions, they rather become proactive tools performing the assigned task (or some of its parts) by taking autonomous decisions, based on sensorial signals provided by their sensors.

Therefore, more and more such 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 case the task is only partially automated.

Where is our role as Signal Processing researchers in Autonomous Systems research? Well, since 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 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/labels as signal processing output. Segmentation of video sequences or speech can be such examples. Some of us are used to work up to semantic signal analysis level, by providing semantic labels to signal segments and associating a meaning to such labels. This goes towards pattern recognition that, 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, intelligent buildings (and much more to come) will be the agents we have to provide solutions for. Video, acoustic, tactile, radio signals will be just some of the sensorial signals that should be processed by an agent in real time e.g.:

- to interpret the external situation in which it operates;
- to relate such 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 sub-symbolic and symbolic level the reasons of its own choices.

Over the last decade, researchers have been proposing and investigating computing systems with advanced levels of autonomy, in order to manage the ever-increasing requirements in complexity. An autonomous system (AS) is an artificial system able to perform a certain number of tasks with a high degree of autonomy. Many real-world systems frequently experience non-stationary conditions (i.e., unknown situations) due to uncertain interactions with the environment (incl. human agents) and users, failures or structural changes. AS aim at building up behavior rules over time by learning through interactions with the environment with complex perception-action cycles, towards dealing 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 like adjusting for new methods of accomplishing its tasks or adapting to changing surroundings. From an industrial point of view, AS have exhibited an 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 AS:

- In AS perception, signal analysis is important for any perception modalities, e.g., visual, sonar/ultrasound, laser, radio/GPS.
- In AS communications, signal (e.g., video) compression, transmission and error resilience are very important aspects.
- In AS action, adaptive signal processing can play an important role in AS command and control.

The IEEE Signal Processing Society recognized the immensity of the challenges task ahead and the research potential and launched the Autonomous Systems Initiative (ASI), during ICIP2018. 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

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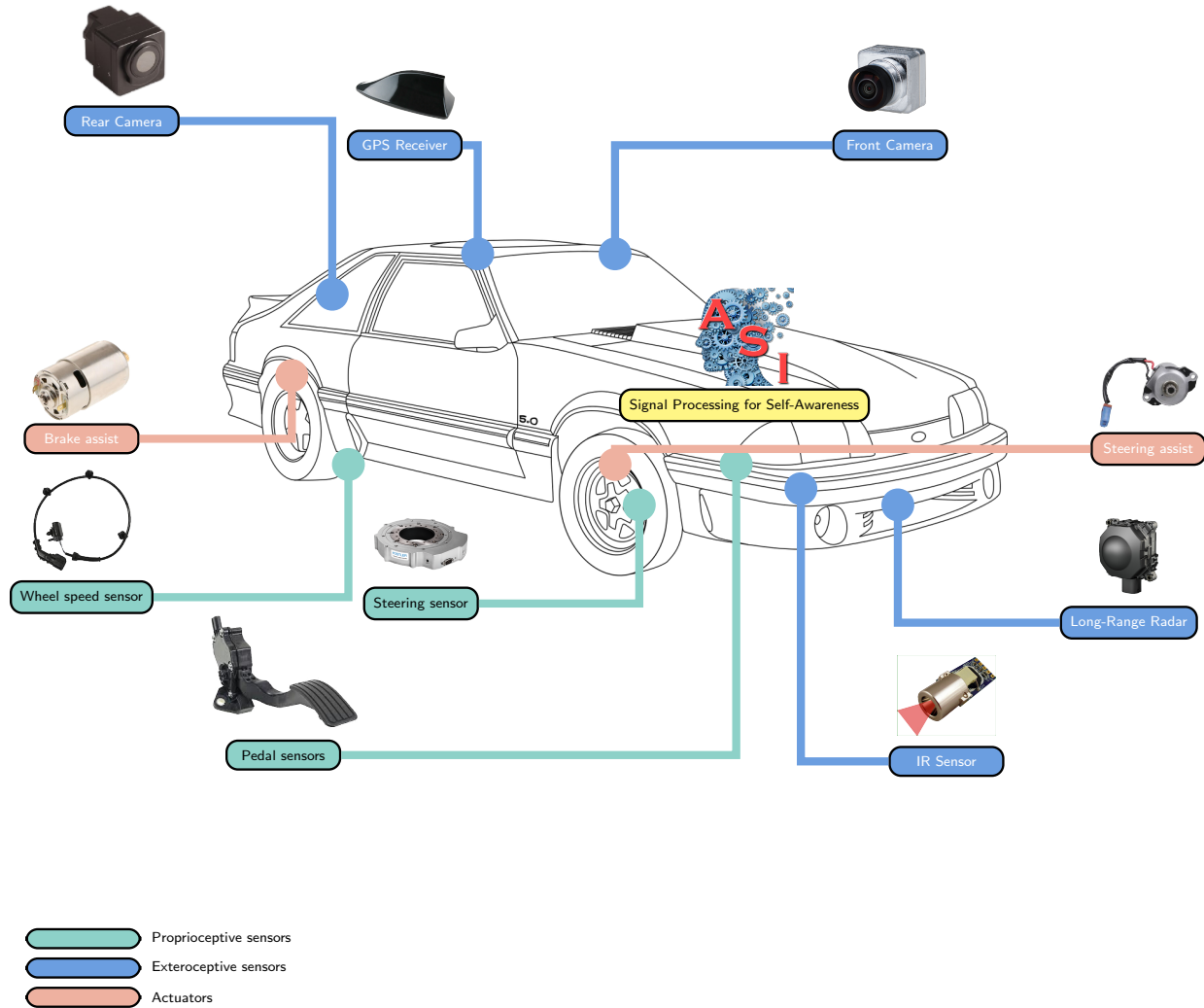
Fig. 1: Architecture for a self-aware autonomous system. The autonomous vehicle observes the surrounding environment with exteroceptive sensors (blue) and its internal state with proprioceptive sensors (green) and translates its autonomous decisions into actions through the actuators (in red). The self-awareness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

- Security
- Societal issues, e.g., data protection, privacy.

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

- 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 in the related industry. To this end, it will cooperate with all relevant SPS TCs, who will have representatives in ASI. The creation of SPS megatrend ASI will boost SPS involvement in this important and expanding area and will allow interaction with other IEEE Societies. Furthermore, it will allow interfacing to other related scientific communities and industrial bodies.

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

Proposals on ASI related activities (e.g., courses, special sessions/issues, workshops, competitions) for synergies within IEEE SPS, IEEE societies and other scientific communities and relevant industrial bodies are welcomed from anybody who can send an email to the ASI chair Prof. I. Pitas and/or the ASI vice chair Prof. C. Regazzoni.
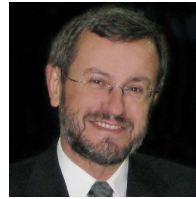
I. AUTHORS

Carlo Regazzoni (IEEE Senior Member) is Professor at Polytechnic School of University of Genova. He is involved in research on Signal and Video processing and Data Fusion since 1988. His current research interests are: Cognitive Dynamic Systems (CDS), adaptive and self-aware data fusion, machine learning, software and cognitive radio. He is one of the pioneering researchers in Intelligent Video Surveillance. He created in 1998 Int. IEEE Int. Conf. on Advanced Signal and Video Surveillance Systems (AVSS). He is author or co-author of more than 100 papers on Journals and of 400 papers in conferences/ book chapters (h-index Google Scholar 40). He served within IEEE SPS in different positions including IEEE SPS VP Conferences (2015-2017). He is currently vice chair of IEEE Autonomous Systems Initiative (ASI).

Ioannis Pitas (IEEE fellow, IEEE Distinguished Lecturer, EURASIP fellow) is a Professor at the School of Informatics of the Aristotle University of Thessaloniki, Greece. His current interests are in the areas of autonomous systems, machine learning and computer vision. He has published over 1100 papers, contributed in 50 books in his areas of interest and edited or (co-)authored another 11 books. He participated in 69 R&D projects, primarily funded by the European Union. He has 28700+ citations to his work and h-index 81+ (Google Scholar). Prof. Pitas leads the big European H2020 RD project MULTIDRONE. He is chair of the IEEE Autonomous Systems Initiative (ASI).