Guest Editorial Special Issue on Sensors in Machine Vision of Automated Systems

SENSORS in machine vision of automated systems significantly improve the quality and reliability of all those processes and products related with such automated systems.

In the variegated scenario of possible sensors or virtual sensors, the most important characteristic of them is that they represent the interface of technical systems with the environment to detect physical, chemical, and/or biological phenomena for a wide range of applications. Recent advances in technology have emerged the design and construction of a wide gamma of sensors with powerful capacities. Most of them are integrated with signal conditioners, data processing, interconnect ability, and power units. Sensors in machine vision applications enable engineering systems with visual properties that could exceed the human visual ability. With the use of the appropriated sensors, machine vision systems can measure specific coordinates, selected objects, or a whole scene. This way, reality can be imagined and augmented in comparison with human image perception. Machines and humans will cooperate, as well as different components at different levels: actuators, sensors, and their corresponding virtual versions, such as virtual actuators, virtual sensors. It plays an important role in the context of the functionality, safety in the presence of fault, and optimization aspects.

The broad application of sensors in machine vision for automated systems includes aerospace and terrestrial transportation systems, any kind of industrial automation, process control, residential security, indoor and outdoor surveillance, smart buildings, smart cities, structural health monitoring, medical diagnostic systems, health monitoring, pharmaceutical, energy generation and water treatment distribution and monitoring, agriculture, military systems, robotics, and automated guided devices.

On the other side, interconnectivity and cloud computing, as well as the big capacity of data processing and storage, have carried out to continue real-time and online sensing. It drives to the development of novel algorithms in response to new statistical data processing methods and techniques, the artificial intelligence.

This scenario is the essence of our current industrial revolution which is called Industry 4.0. Cyber-physical systems (CPSs) are the neologism of this epochal revolution. CPSs are network components that coordinate their physical actions with each other. They can act autonomously and exchange the data required and control each other.

A. Industry 4.0 as a Sensoring Revolution:

This epochal industrial revolution is connected with the revolution of the sensors and the sensing strategies. New sensor generations represent the most innovative and leading trend of our time.

At least one microcontroller is integrated into every electrical device today. This allows us to say that a multitude of wireless communication units will be found in the future. This is possible just if we think of our technological environment more and more in connection with sensors and measurement technology. Several driving political forces and institutions are accelerating this development.

The ambitious goals are future projects such as smart cities, smart grids, and smart factories. Many companies are to be positioned as a provider and user of new and future-oriented technologies for industrial production. Internet-based recording of the environment and interaction and further advancing the autonomy of systems through increasing cognitive skills is a trend now. It is important to master the growing dynamics and complexity of the processes through intelligent procedures that include monitoring, analysis, modeling, independent communication, and (self) control. Machine vision is a futuristic field in which advanced algorithms enable to perceive not only image but also to interpret them.

As miniaturization continues, new areas of application are constantly being opened up on the way to an intelligent environment. This is called "Ambient Intelligence," and it is in this context that we can speak about some main technological trends: from sensors to intelligent technical systems.

B. Sensors and Cyber-Physical Systems in Machine Vision:

CPSs stand for the connection between the physical (real) and information technology (virtual) world. They arise from a complex interaction such as embedded systems (application systems and infrastructures) on the basis of their networking and integration and the human–technology interaction in application processes.

Essential components of CPSs are powerful embedded systems, which are already cooperating and networked as closed systems. Localized and increasingly mobile sensor, regulation, and control services exist in the automotive, aviation, and production sectors in particular. The future projects are based on cyber-physical systems and "intelligent technical systems." CPSs control things in the real world from the cloud, record sensor data, and regulate and optimize information, energy,

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material, goods, and people flows. For this reason, several orders of magnitude more sensors, circuits with new properties as well as platforms for safety and quality-related hardware and software are required. It is only a matter of time. A large number of new requirements are derived from the sensor and measurement technology in order to make the increasing complexity manageable. In addition, taking into account established in the last years' development of preferred integration of online retailing (virtual marketplace) with unmanned automated delivery, we can get the global conclusion: this informational/technologic process very soon will change totally the usual life of the human community. It will convert from the narrow scientific area, interesting only for specialists, into a powerful global trend changing the usual way of industry, and even the bases of the global economy as a whole.

The sensor and sensing strategies in machine vision must be further developed with the following properties:

1) Physical situation recognition (sensor fusion, virtual sensors, pattern recognition, situation maps).
2) Anticipatory, autonomous action (impact assessment).
3) Cooperation and behavior (multi-agent system, group behavior, shared control).
4) Human–machine interaction (interaction rules and cooperative control).
5) Machine learning (CPS systems adapted to their users or situations—personalization).
6) Strategy of self-organization and adaptation (self-organization in of production, whereby workpieces themselves become information carriers and shape production processes).

Direct introduction of sensors to the measurement of objects sizes and the introduction of new types of measurement methods for the acquisition of spatially distributed measurement data and use of self-sufficient and wirelessly communicating sensors (*ad hoc* networks) characterize the central sensor in machine vision.

Sensor fusion with the correlation of weighting, interpretation, time sequences together with virtual sensors, derived from models as observers, or "real" sensors equipped with software represent traditional, but in the meantime, future field of research. In this sense, the traditional algorithms, used in the context of data analysis and reconciliation for sensors such as Kalman Filters, Particle Filters, and more in general algorithms dedicated to the integration of sensors, will play more and more a central role in applications.

Energy self-sufficient sensor and microsystems that supply themselves with energy from their environment, record data with the least amount of energy, and forward it wirelessly are key components for new types of applications.

Today's wireless communication technologies allow *ad hoc* networking and a connection to powerful computing systems and databases. With the trend toward further miniaturization in technology and the increasing performance of the smallest devices (only during the last decade the novel term MEMS tends to prefix-change to "nano"), it is becoming clear that completely new possibilities and requirements for device support are emerging for mobile users, as well as "machine to machine" (M2M) communication in which sensors play a crucial role. The focus for a large number of M2M applications is the wireless exchange of information to optimize business processes. In this sense, the most important areas of application include transport and logistics, fleet management, remote monitoring, control, measurement, security technology, and healthcare. Last but not least, buildings of the future will be fully covered by information technology, like cars. The application scenarios show that in the convergence of sensor technology, sensing strategies through algorithms and mobile communication for machine vision, considerable potential benefits can be obtained.

In the context of this entire panorama related to smart sensors, machine vision, automated devices, and artificial intelligence, the proposed special issue considers these challenges and cover many technological and scientific aspects in the field of machine vision of automated systems. The main objective of this Special Issue is to show the state of art in theory, design, fabrication, manufacturing, and application of devices for sensing in machine vision, and highlight electronics and physical aspects of sensors and integrated sensor-actuator technologies, as well as novel mathematical methods for advanced processing of sensors signals and applications of artificial intelligence for machine vision capability improvement.

It provides a reference on machine vision supporting techniques for measurements, 3-D reconstruction, automated systems tasks, and navigation for researchers and engineers.

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