Vision Paper on “Functional Electronics” as Enabler for Autonomous Operation of Machines

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5E - Federating European Electronics Ecosystems for Competitive Electronics Industries
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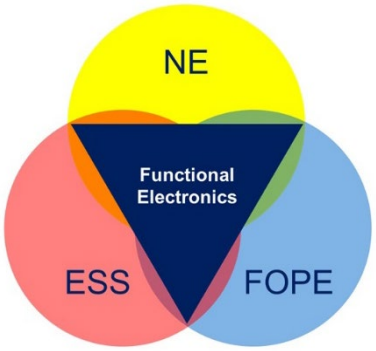
"Functional Electronics" definition

At the convergence of unconventional nano-electronics (NE), flexible, organic & printed electronics (FOPE) and electronic smart systems (ESS), the term 'Functional Electronics' encompasses this ever-increasing capability to integrate key digital technologies with cognitive functions, shifting from purely physical integration to functional integration. Smarter (hybrid) electronic components and systems will become viable notably at high structural density on and in novel substrates (including, but not limited to, flexible, organic, printed) and structural systems (e.g. textiles, plastics, laminates, glass, steel).



Functional Electronics will generate additional value from their use that is presently not realisable by using electronics forms independently, enabling new and efficient eco-design approaches at product, process and business model levels. They will have capability to capture & manage multi-physics data and contextual information in real time, with high sensitivity, selectivity and reliability as well as being networked, autonomous and complemented by bespoke software (incl. AI) solutions. Functional Electronics allow for their seamless integration in everyday objects and thereby enable the full realisation of their sustainability benefits in a broad spectrum of new applications.

1. Introduction

Autonomy can be defined as the capacity to make an informed and uncoerced decision [1]. Autonomously operating machines (e.g. self-driving cars, smart home, self-orchestrated production etc.) promise several key benefits: they can act quicker, more efficiently and economically, do not get tired, maintain their precision, deliver consistent and highest quality at reduced lead times and error rates etc.

Former visions of completely deserted factories and ubiquitous driverless vehicles are replaced meanwhile by aspired cooperation of autonomous entities in a joint approach with human experience and flexibility where needed for the superior benefit. Also, autonomy nowadays is no longer regarded as a binary characteristic (achieved vs. not achieved), but different levels of autonomy have been defined and commonly accepted – notably in the automotive field [2].

Undoubtedly, autonomous operation of machines enabled by **self-learning and adaptable systems** will increase the quality of our lives. It is, however, an essential prerequisite that the enabling electronics provide safe and reliable operation under any circumstances. This makes the availability of appropriate Functional Electronics an inevitable requirement for the autonomous operation of machines.

2. Background Information

Automated processes based on **electronic control systems** have already reached a global industry level. Characteristics are among others large horizontal and vertical integration as well as a strong interaction by means of the "**Internet of Things**". Autonomous operation is an objective reaching well beyond this.

Per se, all electronics are "deaf, dumb and blind". Every action electronics should execute must be defined in detail by persons designing or programming them.

Similarly to human decisions and autonomy, which are based on comprehensive knowledge, experience and the ability to assess information quickly, purposefully and "in the right way" –

the degree of autonomy for machines is necessarily based on '**Functional Electronics**' (definition in the appendix) integrating:

- multi-functional sensor systems providing information
- processing capacities to compare a given situation to data available in a "knowledge base"
- algorithms enabling predictive and adaptive actions, and last but not least
- actuators to influence the environmental situation (e.g. to stop the self-driving car before an accident occurs)

Furthermore the current developments in the field of **Artificial Intelligence (AI)** promise to provide new abilities to machines to learn from their environment or co-workers. This creates the challenge of an „**explainable AI**", ensuring that electronics execute correctly the intended tasks and that all options defined by the Artificial Intelligence are comprehensible and verifiable so that humans remain in control. Nevertheless, autonomous operation means that algorithms take decisions that influence the tangible world around us. Requirements for algorithms therefore have to satisfy even higher ethical standards than human action itself can meet at all. However, pivotal questions linked to the related ethical challenges and ultimate responsibilities cannot be conclusively answered here.

3. Obstacles

As a matter of fact, there are **weak points in the available technologies that have to be improved**, as well as strong reservations in the general public that have to be cleared up before the stepwise or even complete transition towards the autonomous operation of machines can be successfully accomplished. Here, we specify just some of them:

- machines lack intuition, gut feeling, common sense, creativity, improvisation talent etc
- if not properly guided, self-learning systems learn undesirable practices and "behaviour" patterns
- it is difficult to trace what exactly a self-learning system has actually learned. Often this can be merely concluded from its actions
- sensors can be manipulated e.g. to provide negative reports or to detect non-existent objects
- autonomous systems per se are more vulnerable to attacks than conventional systems

4. Conclusions

The implementation of the vision of autonomous operation of machines requires systems comprising of Functional Electronics to establish **smart networks with nodes on all relevant assets**: equipment, infrastructure, environment, movables, feedstock, products etc. – and finally the affected persons themselves.

- Well-defined and powerful hardware and software interfaces ensure the connection of all relevant entities as well as the flexibility to integrate additional devices, components, sensors etc.
- All processes must become transparent providing the possibility to be virtually monitored. Self-organised actions must be executed in a safe and secure, resilient and zero-failure environment.
- All related objects and processes from the tangible world need to be digitally represented as well (keyword: digital twin).
- The affected persons are supported with the right information at the right time to achieve full awareness of the situation, to allow for action and regaining of control whenever necessary (keyword: level of autonomy).

To **empower Functional Electronics as enabler for autonomous operation** of machines the 5E project suggests **a priority for the following issues in Research, Development, and Innovation (R&D&I)**:

- Next generation distributed sensor systems and actuating as key functionality for safe, efficient and optimised autonomous processes
- Integrated hardware and software platforms for future products in the Edge IoT domain, combining extreme power efficiency with robust neuromorphic computing capabilities
- Integrated neuromorphic hardware with improved energy efficiency using emerging technologies (e.g. new memory, chips architecture…)
- Self-repairing equipment that continuously analyses its own condition
- Self-learning multi-sensing capability to monitor complex environment via extended networks of connected devices that allow event-based predictions
- Capability for Big Data analysis embedded in Functional Electronics to allow for integrated control loops and reactions on short notice
- Efficient and secure protocols and data transfer technologies for flexible and adaptable IoT systems to enable trusted solutions in data communication
- Creating visibility or conveying information as instructive or preventive action to promote effective operation and physical safety
- Autonomous systems with a "trusted label" for protection of people and goods to be easily integrated into products, processes, and services

To achieve the desired objectives it is also necessary to analyse and describe meticulously how the autonomous operation of machines shall be successfully ramped up and in a socially acceptable manner in each individual case, and in general as well; Processes have to be entirely redesigned, core competences need to be re-evaluated, and education and training have to adapt to the changing environment.

5. Recommendations

To strengthen European Sovereignty in the autonomous operation of machines and the development of the enabling Functional Electronics, we support and widen the recommendations already given by **EPoSS** in its respective position papers on automation [3]:

- set a legal framework for the development, testing and use of autonomously operating machines
- discuss liability issues with the stakeholders (industry, academia, public authorities)
- foster a joint integration strategy based on e.g. a set of certain successive autonomy levels
- establish centres for knowledge transfer of best practice into all relevant sectors and domains
- create Living Labs to test technological achievements and to include the general public

Driven by the requirements for the autonomous operation of machines, in the future the seamless merging of multi-functional electronics is to be expected. The related synergies between suppliers and users of electronics will most likely generate great potential for disruptive innovations emerging from a strong European ecosystem in electronics, covering trusted fab facilities, researchers and appliers as well.

Contribution/Support

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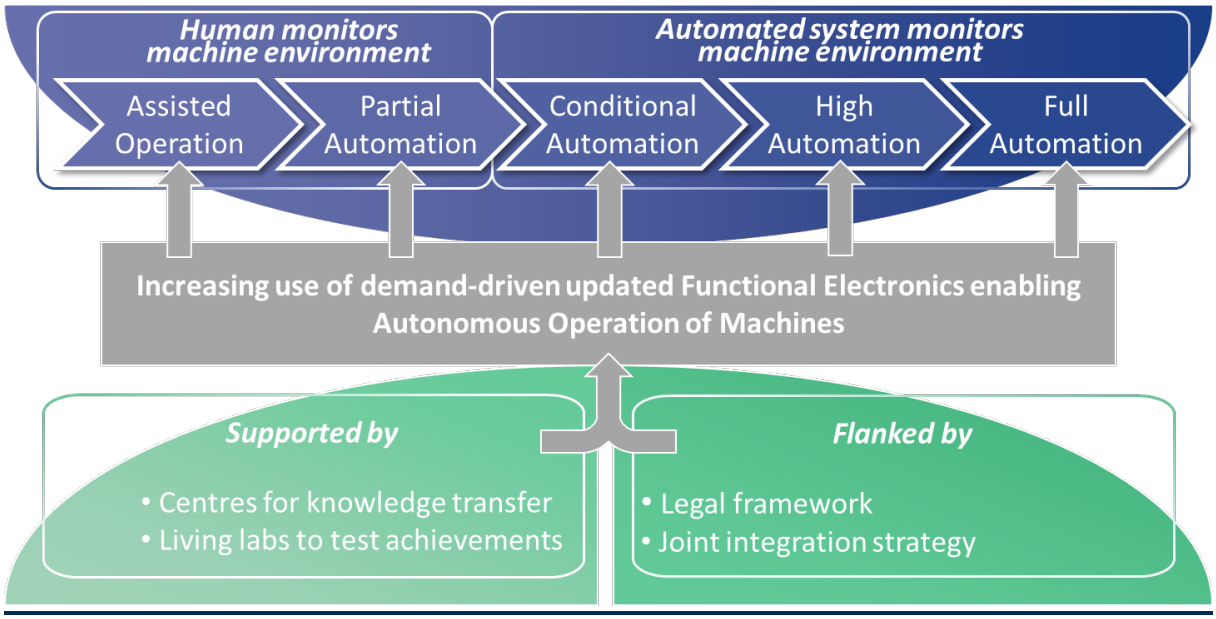

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in analogy to the increasing automation levels for self-driving cars, following approach is recommended for a stepwise implementation

This Vision Paper is a result of the 5E project that reinforces collaboration and outreach of the electronics industry across Europe and supports its stakeholders in seizing opportunities.

[1] https://en.wikipedia.org/wiki/Autonomy
[2] "U.S. Department of Transportation Releases Policy on Automated Vehicle Development". National Highway Traffic Safety Administration. Retrieved 9 December 2016
[3] EPoSS Position Paper: Smart Systems for the Automated Hospital, see https://www.smart-systems-integration.org/publication/position-paper-smart-systems-automated-hospital
EPoSS Position Paper: Smart Systems for the Automated Factory, see https://www.smart-systems-integration.org/publication/position-paper-smart-systems-automated-factory