Opportunities and challenges in embedded systems

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Abstract

The technological advances in processing, communication, storage, actuating and sensing enables a large amount of applications of embedded systems. The challenges of today to realize these opportunities are discussed, addressing six main issues: market dynamics, interoperability, reliability, power, security, and creativity.
The capabilities of the Embedded Systems Institute are discussed briefly.

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1 Introduction

The field of embedded systems design is very broad, ranging from small systems, such as chips, unto large systems such as MR scanners or wafer steppers. The design of these systems can be characterized by the combination technology intensive, to interface and interact with the physical world, and software intensive, to create the desired functionality and integration. A lot of skills are needed to create these systems where all the emerging qualities of the system match with the needs of the user of the system.

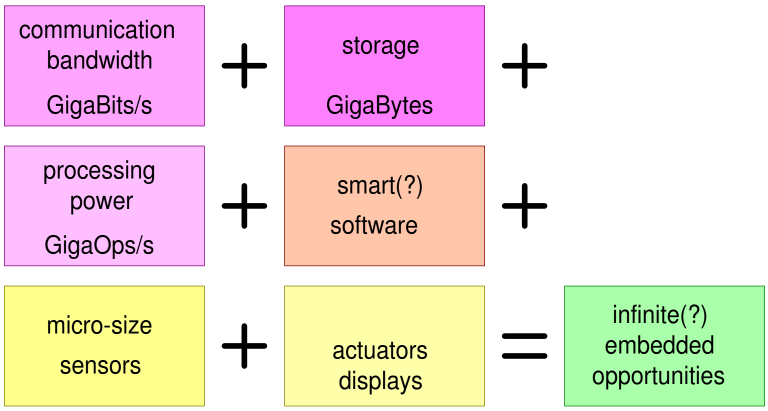

Figure 1: The fast improvement of many fundamental technologies creates Giga embedded opportunities

In this article we identify the challenges in Embedded Systems Design, based on the trends in the world both at the customer side and at the technology side. The starting point of the analysis is the observation that the tremendous technological developments create many opportunities, see Figure 1.

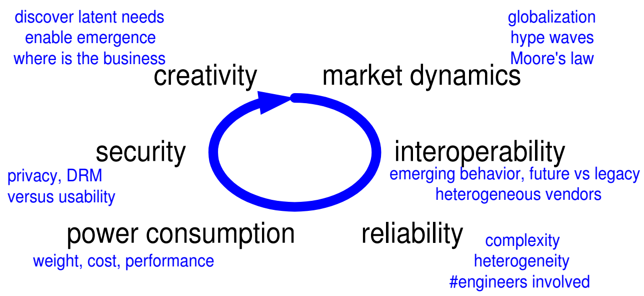

Figure 2: Hit list of challenges

The world of high tech product development faces a number of challenges, summarized in figure 2. Section 2 discusses the *market dynamics*. Section 3 expands the *interoperability* issue. The *reliability* is discussed in Section 4. *Power consumption* is elaborated in Section 5. Section 6 addresses the tensions between the many *security* related viewpoints. The analysis is finished in Section 7 by discussing the *creativity* as limiting factor in product creation.

This article reuses previous material from [2] and [3].

2 The Dynamic Market

In this section two examples of a dynamic market are given. The first example is the semiconductor market, discussed in Subsection 2.1. The second example is from the medical domain, described in Subsection 2.2.

2.1 The Dynamics in the Semiconductor Market

Philips Semiconductors (PS) plays a part in a longer value chain as depicted in figure 3. Typical the components of PS, such as single chip TV's, are used by system integrators, which build CE appliances, such as televisions. These appliances can be distributed via retail channels or via service providers to end consumers.

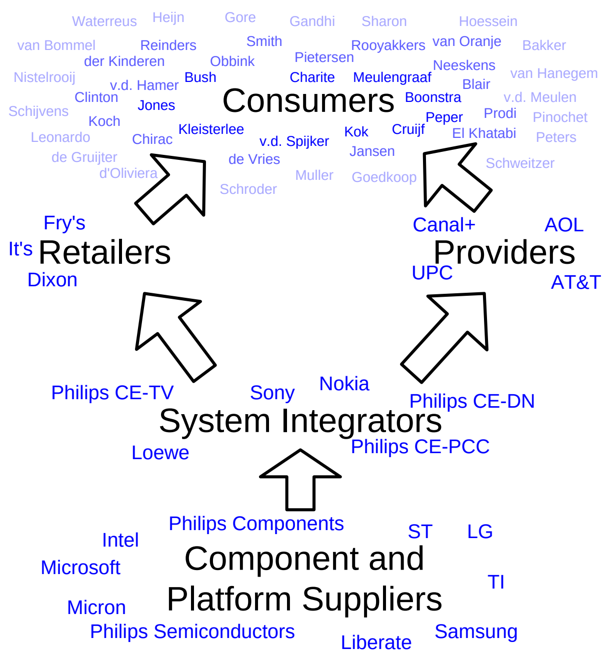

Figure 3: Value chain

One of the major trends in this industry is the magic buzzword *convergence*.

Three more or less independent worlds of *computers*, *consumer electronics* and *telecom* are merging, see figure 4; functions from one domain can also be done in the other domain.

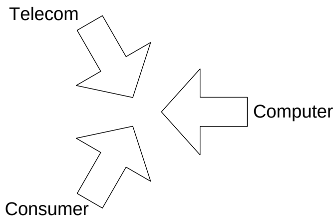

Figure 4: Convergence

The name convergence and the visualization in figure 4 suggest a more uniform set of products, a simplification. However the opposite is happening. The convergence enables integration of functions, which were separate so far for technical reasons. The technical capabilities have increased to a level, that required functionality, performance, form factor and environment together determine the products to be made. Figure 5 shows at the left hand side many of today's appliances, in the middle many form factors are shown and the right hand side shows some environments.

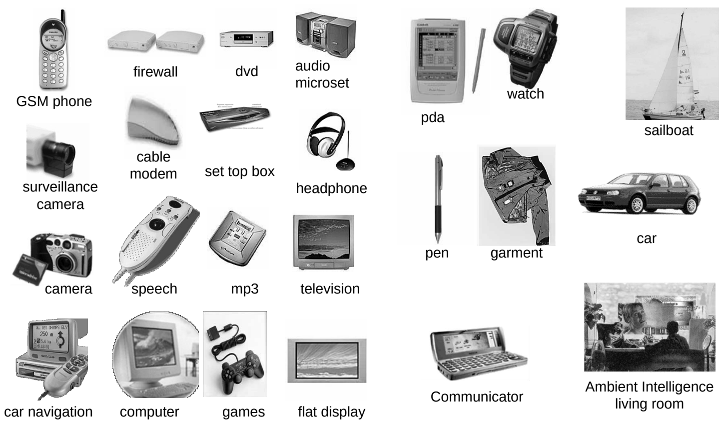

Figure 5: Integration and Diversity

Note that making all kind of combination products, with many different form factors for different environments and different price performance points creates a very large diversity of products!

Figure 6: Uncertainty (Dot.Com effect)

Another market factor to take into account is the uncertainty of all players in the value chain. One of the symptoms of this uncertainty is the strong fluctuation of the stock prices, see figure 6.

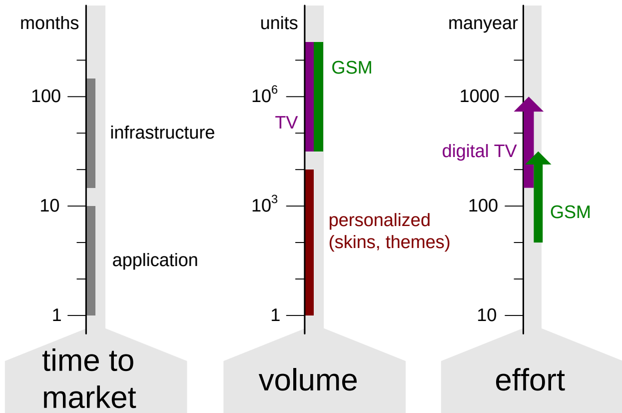

Figure 7: System Integrator Problem Space - Business

From business point of view the products and/or markets of the system integrators can be characterized by *time to market*, *volume*, *effort to create*. In these 3 dimensions a huge dynamic range need to be covered. Infrastructure (for instance the last mile to the home) takes a large amount of time to change, due to economical constraints, while new applications and functions need to be introduced quickly (to follow the fashion or to respond to a new killer application from the competitor). The volume is preferably large from manufacturing point of view (economy of scale), while the consumer wants to personalize, to express his identity or community (which means small scale). As mentioned before the effort to create is increasing exponentially, which means that the effort is changing order of magnitudes over decades. Figure 8 summarizes these characteristics.

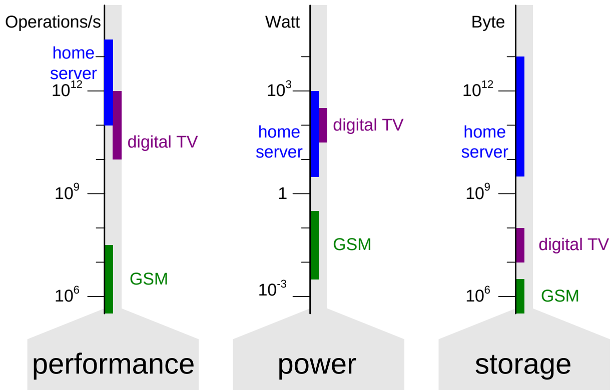

Figure 8: System Integrator Problem Space - Technology

Main technology concerns of the system integrators are *performance*, *power* and *storage*. Again a huge dynamic range need to be covered in these dimensions. Video based applications have much higher processing demands than GSM speech audio. While for power portable appliances like a GSM have severe constraints and should use orders of magnitude less power than TV's or set top boxes. The amount of storage is again highly function dependent, for instance a home server which must be able to store many hours of video needs a huge amount of storage, while the address book of a GSM phone is very limited in its storage needs. The technology parameters and dynamic range are visualized in figure 8.

Combining the figures in one picture enables the visualization of a system profile. Figure 9 shows the profiles for a digital TV and for a GSM cell phone.

2.2 Dynamics in the Medical Market

The market is changing continuously and the frequency of changes is high. Figure 10 shows several forces operating on the PMS market.

Companies from other domains are changing the playing field. Especially gen technology (early risk indication, preventive examination and therapy?), pharmaceutics (focused and localized application of medicines) will change the clinical field quite a lot.

Information Technology suppliers and service providers, integrate all types of information and applications in networks of systems. This integration enables new applications and also influences the conventional system boundaries and function allocations.

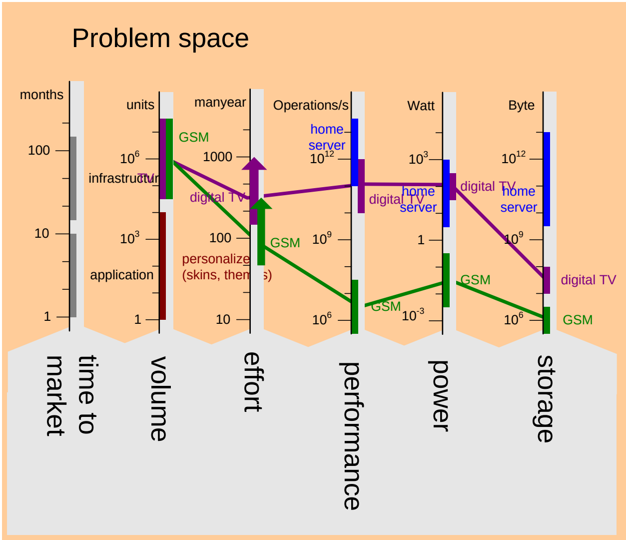

Figure 9: System profile

Government have a strong influence on the health care systems. Current trends are towards cost reduction and cost control in attempt to keep health care provisions affordable for the entire population. At the same time increased privacy awareness and concerns result in new and more regulations, with far stretching consequences for most clinical systems. The current threat of terrorism will also influence system requirements.

A global trend is an aging population, which has a considerable impact on the consumption of clinical services. Also new diseases appear, which creates unforeseen needs.

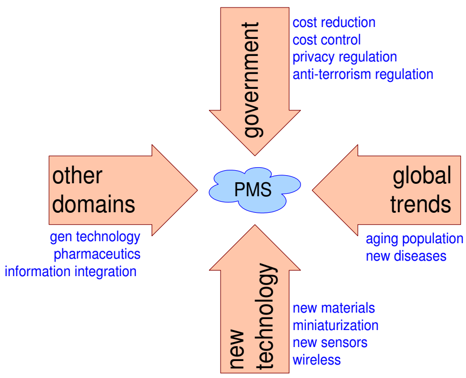

Figure 10: Market dynamics in medical

The rapid advance in many technology areas (for example new materials, miniaturization, new sensors, and wireless) opens up many new possibilities.

3 Interoperability

Systems get more and more directly connected. In the past humans linked the different systems together, applying intelligence and adaptations were needed. In the electronic age the adaptation must take place in the systems themselves.

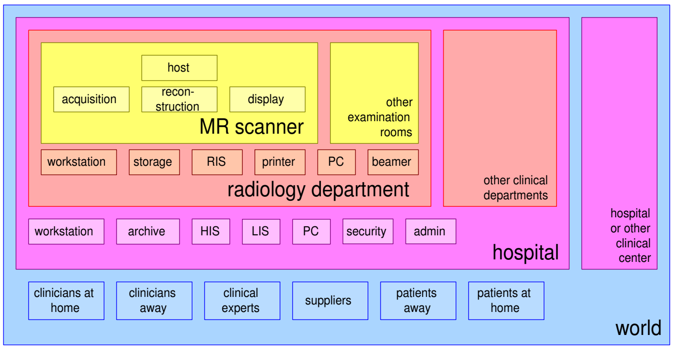

Figure 11: Interoperability: systems get connected at all levels

Figure 11 shows that systems all levels in the hospital get connected. Connectivity is not sufficient to justify the integration cost, only if systems interoperate in a useful way true added value is created.

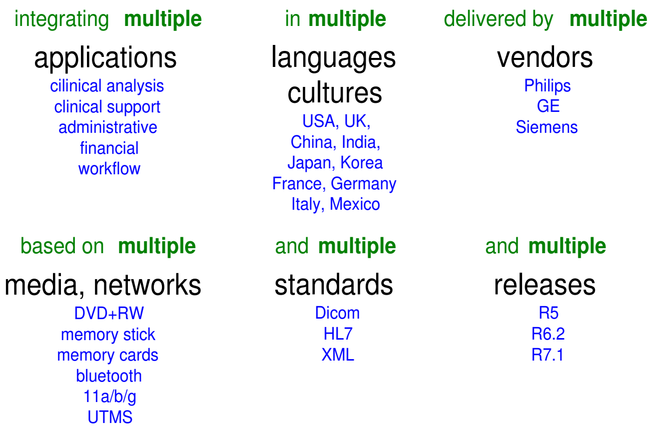

Figure 12: Multi dimensional interoperability

An additional challenge for interoperability are the many dimensions in which interoperability is required, as shown in figure 12:

- applications
- languages, cultures
- vendors
- media, networks
- standards
- releases

4 Reliability

The amount of software (and technology) in products is increasing exponentially, as shown for televisions in Figure 13. Many other products show the same growth in the amount of software: Cardio Vascular X-ray systems, MRI scanners, wafer-steppers.

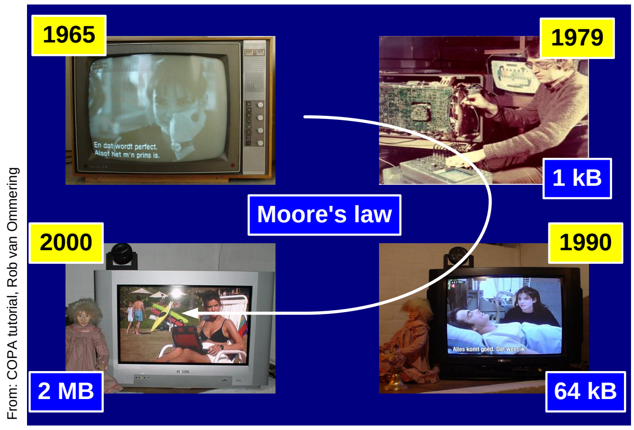

Figure 13: SW increase in televisions

Software is far from errorless. Studies of the density of errors in actual code show that 1000 lines of code typically contain 3 errors. In case of very good software processes and mature organizations this figure is 1 a 2 errors per kloc, in poor organizations it can be much worse.

Incremental increase of the code size will increase the number of hidden errors in a system also exponentially, as shown in figure 14[1].

Note that the *interoperability*, as described in Section 3 increases the *reliability* threat with a multiplying factor.

[1] Simple systems, which already contain fatal bugs are appearing: for instance software vending machines, which need a power down when the software is crashed.

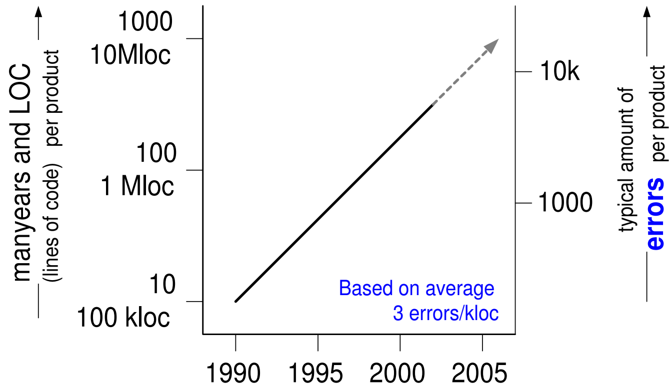

Figure 14: Increase of software threatens Reliability

5 Power consumption

Many technological improvements show an exponential increase: circuit density, storage capacity, processing power, network bandwidth. An exception is the energy density in batteries, which is improved, but much less dramatically. The power usage of processing per Watt has improved significantly, but unfortunately the processing needs have increased also rapidly. Overall the power consumption of for instance PC's is more or less constant.

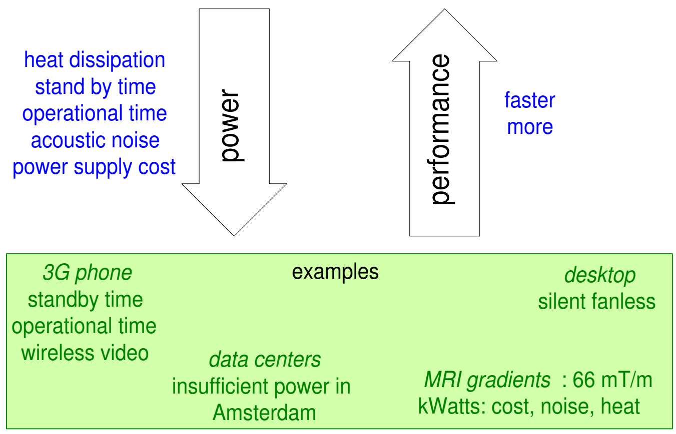

Figure 15: Power consumption and dissipation

Figure 15 shows these opposing forces: the need for less power consumption and for more performance. There are multiple reasons to strive for less power consumption:

- less heat dissipation, easier transport of waste heat

- increase stand by time
- increase operational time
- decrease acoustic noise of cooling
- decrease power supply cost

Power consumption plays a role in all domains, for example in GSM phones (standby time, operational time, wireless video), data centers (Amsterdam cannot accommodate more data centers, due to the availability of electrical power), MRI gradients (faster switching of higher gradient fields, amplifier costs, acoustics and cooling are significant technical challenge) and desktop PC's (where a current trend is to silent fanless desktops).

6 Security

Several stakeholders have significant different security interests. Figure 16 shows 3 categories with different interest and security solutions:

- Government and companies, which implement restrictive rules, which can be rather privacy intrusive
- Consumers, who want to maintain privacy and at the same time usability of services[2]
- The content industry, who want to get fair payment for content creation and distribution. Their solution is again very restrictive, even violating the right of private copies, and characterized by a paranoia attitude: every customer is assumed to be a criminal pirate.

All stakeholders are confronted with threats: pirates, thieves, terrorists, dictators, et cetera. The challenge is to find solutions which respect all the needs, not only the needs of one of the stakeholders. Another challenge is to make systems sufficiently secure, where a little bit insecure quickly means entirely insecure. Last but not least is the human factor often the weakest link in the security chain.

7 Creativity

The rapid technology development has changed the nature of product creation challenges. Several decades ago the main challenge was to get the desired performance at all; Can we **do** it? This shifted to the problem of realizing the performance within practical constraints, such as cost, power and size; Can we **make** it?

The next challenge was to create the product with large amounts of people in a limited amount of time. Processes are a means to create products in large

[2] Which can be quite conflicting. Who may have access to your medical data? Do you still want to control this access in case of emergencies?

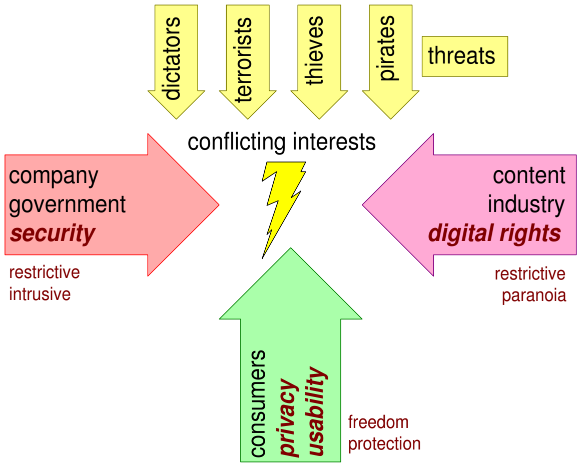

Figure 16: Security conflicting interests

teams; Can we **organize** it? Today many well defined applications and services can be realized, the real problem has shifted to which applications and functions are needed? Which services can be used to sustain a business? Can we **conceive** it?

8 The role of the Embedded Systems Institute

The objective of embedded systems institute is to build up, consolidate and transfer knowledge how to create embedded systems effectively. Figure 18 summarizes the role of the institute by means of an annotated sentence.

To create embedded systems means and methods are needed to specify, design, test and verify, for instance modelling methods. These embedded systems must fulfil the functionality and the quality needs.

Embedded systems are mostly created in an industrial setting, which means that many practical constraints are present during the product creation. The creation methods must cope in a practical way with these constraints. The Embedded Systems Institute cooperates closely with an industrial partner, the so-called *industry as laboratory* approach.

References

[1] Gerrit Muller. The system architecture homepage. `http://www.gaudisite.nl/index.html`, 1999.

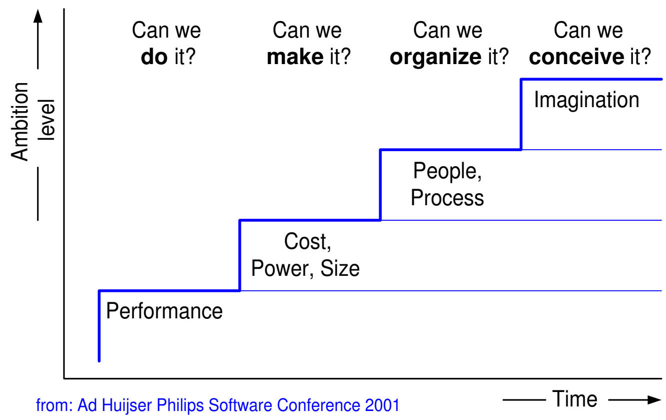

Figure 17: Creativity as limiting factor

[2] Gerrit Muller. Light weight architectures; the way of the future? `http://www.gaudisite.nl/info/LightWeightArchitecting.info.html`, 2001.

[3] Gerrit Muller. Challenges in high-tech, illustrated in the medical domain. `http://www.gaudisite.nl/DYOFPaper.pdf`, 2003.

History

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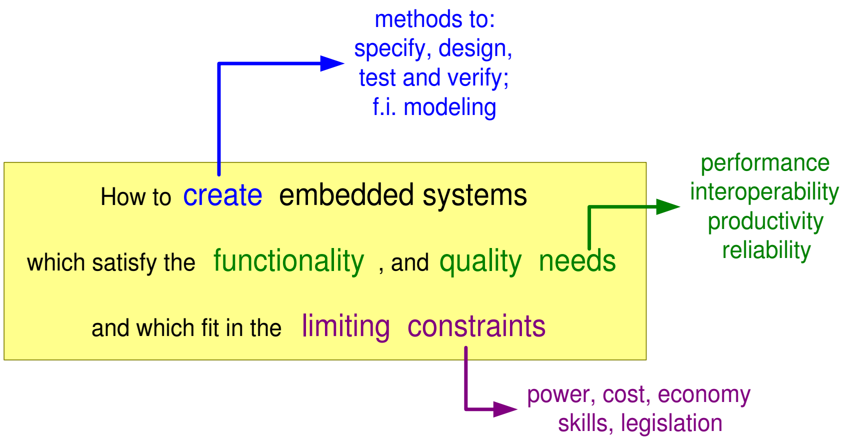

Figure 18: Role of Embedded Systems Institute ESI