SMART4ALL Promotion and Dissemination
Euromicro DSD/SEAA'2020 Conference Event
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SMART4ALL Technologies: *Cyber-Physical Systems and Internet of Things*

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Aims of this presentation

- ***To prepare the ground for the whole SMART4ALL Promotion and Dissemination Action, and***
- ***To briefly discuss the SMART4ALL technologies: CPS and IoT***
- This means in particular:
  - to introduce the SMART4ALL project
  - to introduce CPS and IoT
  - to sketch the CPS and IoT scene, what includes:
    - discussion of the CPS and IoT importance, their ongoing revolution, and challenges of their development,
    - introduction to advanced computing technology and holistic multi-objective quality-driven design needed for advanced CPS and IoT, and
    - discussion of the character and the kinds if innovations possible and needed in the area of CPS, IoT and their applications

Further reading related to this presentation

- Lech Jóźwiak and Radovan Stojanovic, Eds.: Proceedings of CPS&IoT2019, MECOnet Institute (www.meconet.me) and MANT (www.mant.me), June 2019
- Lech Jóźwiak: Advanced Mobile and Wearable Systems, Microprocessors and Microsystems, Elsevier, Vol. 50, May 2017, pp. 202–221
- Lech Jóźwiak: Quality-driven Design in the System-on-a-Chip Era: Why and how?, Journal of Systems Architecture, vol. 47, no. 3-4, Apr. 2001, pp. 201-224
- Lech Jóźwiak: Life-inspired Systems and Their Quality-driven Design, Lecture Notes in Computer Science, Vol. 3894, 2006, Springer, pp. 1-16
- Jóźwiak, L.; Lindwer, M.; Corvino, R.; Meloni, P.; Micconi, L.; Madsen, J.; Diken, E.; Gangadharan, D.; Jordans, R.; Pomata, S.; Pop, P.; Tuveri, G.; Raffo, L. and Notarangelo, G.: ASAM: Automatic Architecture Synthesis and Application Mapping, Microprocessors and Microsystems journal, Vol.37, No 8, pp. 1002-1019, 2013
- Jóźwiak, L. and Jan, Y.: Design of Massively Parallel Hardware Multi-Processors for Highly-Demanding Embedded Applications. Microprocessors and Microsystems, Volume 37, Issue 8, November 2013, pp. 1155–1172.
- Many other papers of myself and my former Ph.D. students; many of them referenced in the above papers
- Jean Paul Gueneau de Mussy: Sustainability Innovation, https://materials-innovation.com/

SMART4ALL project

- **SMART4ALL is a four-year Innovation Action project in CPS and IoT** funded by the European Union's Horizon 2020 Programme under call DT-ICT-01-2019, Grant Agreement No 872614

- The main domains targeted are digitized environment, digitized agriculture, digitized transport and digitized anything

- It enables innovation through knowledge and technology transfer among academic and industrial partners of cross-border Pathfinder Innovation Application Experiments

- **SMART4ALL offers**:
  - funding for Pathfinder Innovation Experiments via 9 open calls;
  - coaching services from world lead experts in technology, funding, etics and business development;
  - support of an extensive network of Digital Innovation Hubs for digital technology uptake and corresponding business development
  - AI based services through Marketplace-as-a-Service.

SMART4ALL project

- Three types of Pathfinder Application Experiments are supported:
  - Knowledge Transfer Experiments (KTE)
  - Focused Technology Transfer Experiments (FTTE)
  - Cross-domain Technology Transfer Experiments (CTTE)
- More information on SMART4ALL will be transferred through the presentations of this SMART4ALL Promotion and Dissemination Action and can be found on: https://smart4all-project.eu/

Program of the SMART4ALL Promotion and Dissemination

- Part 1: ***SMART4ALL Technologies and Innovation Hubs***:

  10.45 – 11.30 Lech Jóźwiak: SMART4ALL Technologies: Cyber-Physical Systems and Internet of Things

  11.30 – 12.15 Radovan Stojanović: SMART4ALL Digital Innovation Hubs

- Part 2: ***SMART4ALL Support Tools and Funding Opportunities***:

  13.30 - 14.15 Georgios Keramidas: The SMART4ALL toolbox for boosting technology and business development in South, Eastern and Central Europe

  14.15 - 15.00 Antonio Montalvo: SMART4ALL Open Calls

What are cyber-physical systems?

- **System** is a ***complex whole composed of interrelated, interdependent and/or interacting items*** (parts or elements of a system) ***that are so intimately connected that they appear and operate as a single unit in relation to the external world*** (to other systems)

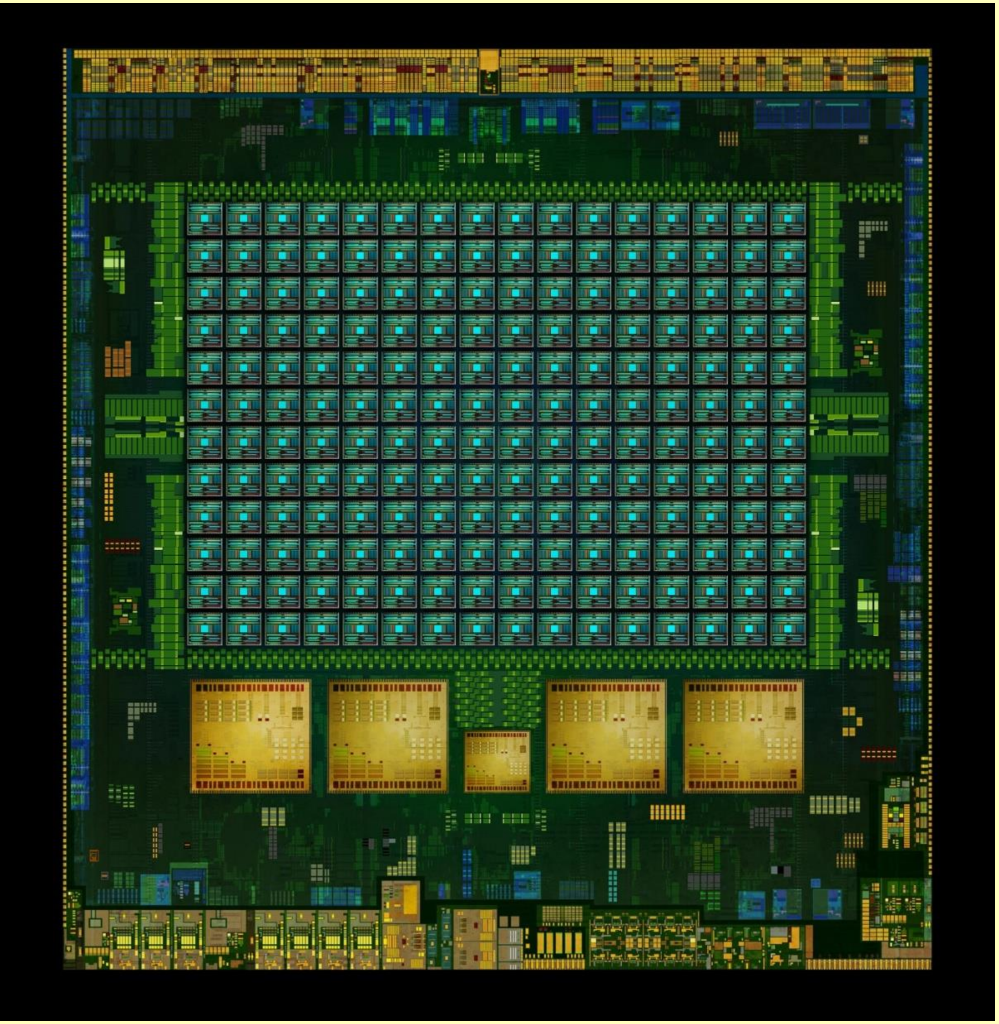
- **Physical systems** are systems in which matter or energy acquisition, processing and transfer take place according to the lows of physics

- **Cyber** comes from Greek adjective ***kyberneticos*** (***cybernetic***) that means skilled in steering or governing

- **Cyber systems** are ***(parts of) control systems***, i. e. information collecting, processing and communicating systems

- **Cyber-physical system (CPS)** is a compound system engineered through integration of cyber and physical sub-systems or components and/or pre-existing component cyber-physical systems, so that it appears and operates as a single unit in relation to the external world (to other systems)

Very complex MPSoCs



- *Modern nano-dimension semiconductor technology enables implementation of a **very complex multiprocessor system on a single chip (MPSoC)***
- **This facilitates a rapid progress in:**
  - ***global networking***
  - ***(mobile) wire-less communication***
  - ***(mobile autonomous) embedded computing***

NVIDIA Tegra K1 massively parallel MPSoC for mobile applications

CPU: (4+1) Cortex-A15 cores

Kepler GPU: 192 CUDA GPU cores

Source: ANANDTECH (http://www.anandtech.com/show/7622/nvidia-tegra-k1)

Introduction: cyber-physical technology revolution

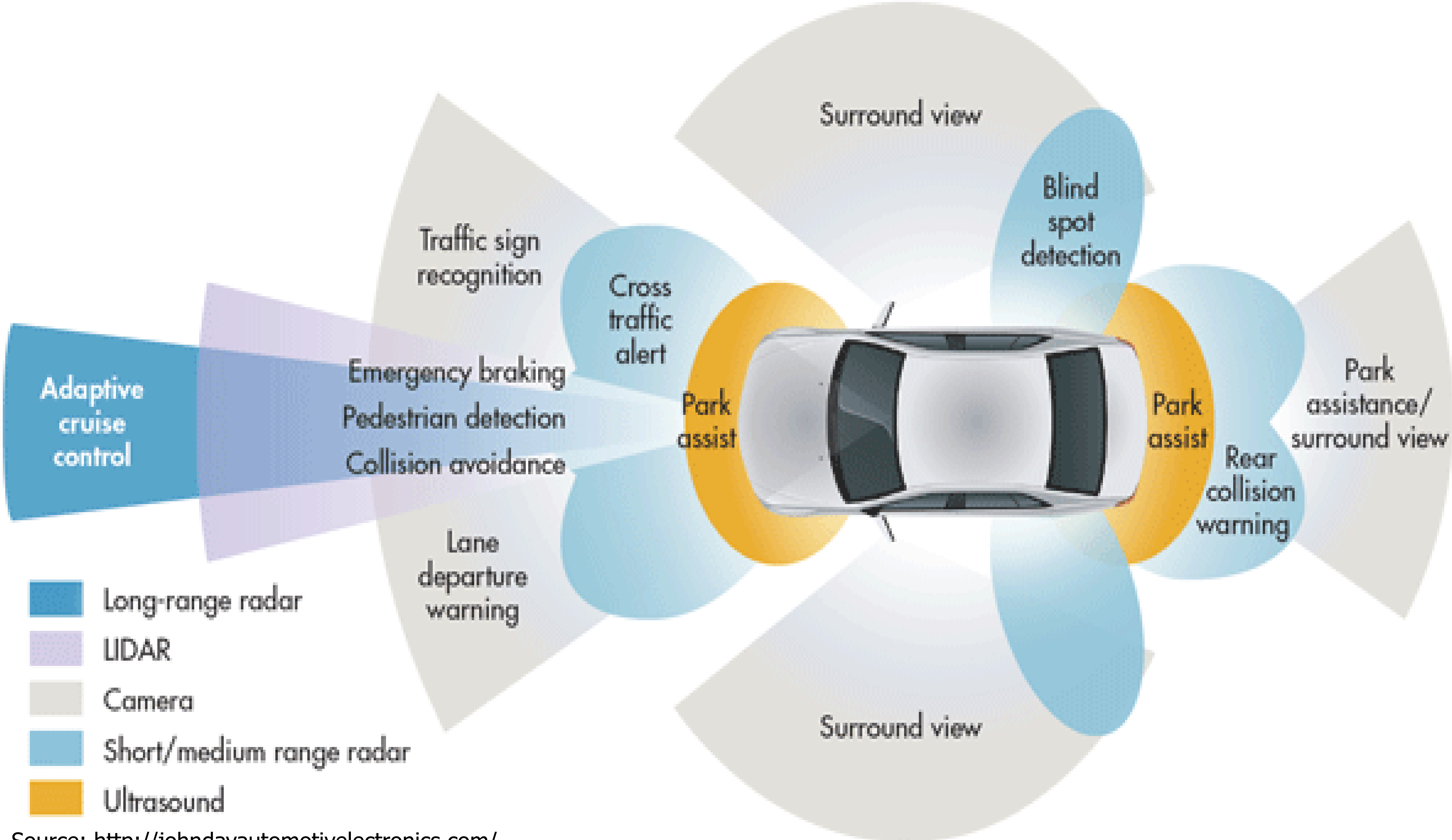
- **The recent rapid developments in:**
  - system-on-a-chip technology
  - common global networking and wire-less communication
  - mobile and autonomous computing
  - miniaturized sensors and actuators
  - material technology

  enable much more effective and efficient "smart" CPS for traditional and numerous new applications, e.g. smart robots, homes, cars, wearable and implantable medical devices, etc. and create a **large discrepancy between what is possible and what is used nowadays**

- This discrepancy:
  - causes both a **very strong technology push** and **market pull** to create new or modified products and services, i.e. **to innovate**, and
  - results in the ***cyber-physical technology revolution***

- Recently, a revolutionary transition has been started from the **internet of computers** to the **internet of smart (mobile) cyber-physical systems (CPS)**, called **Internet of Things (IoT)**

Examples of modern CPS: autonomously-driving cars



Source: http://johndayautomotivelectronics.com/

Examples of CPS: wearable virtual and augmented reality

Source: http://www.technodo.com/

Source: https://www.oculus.com

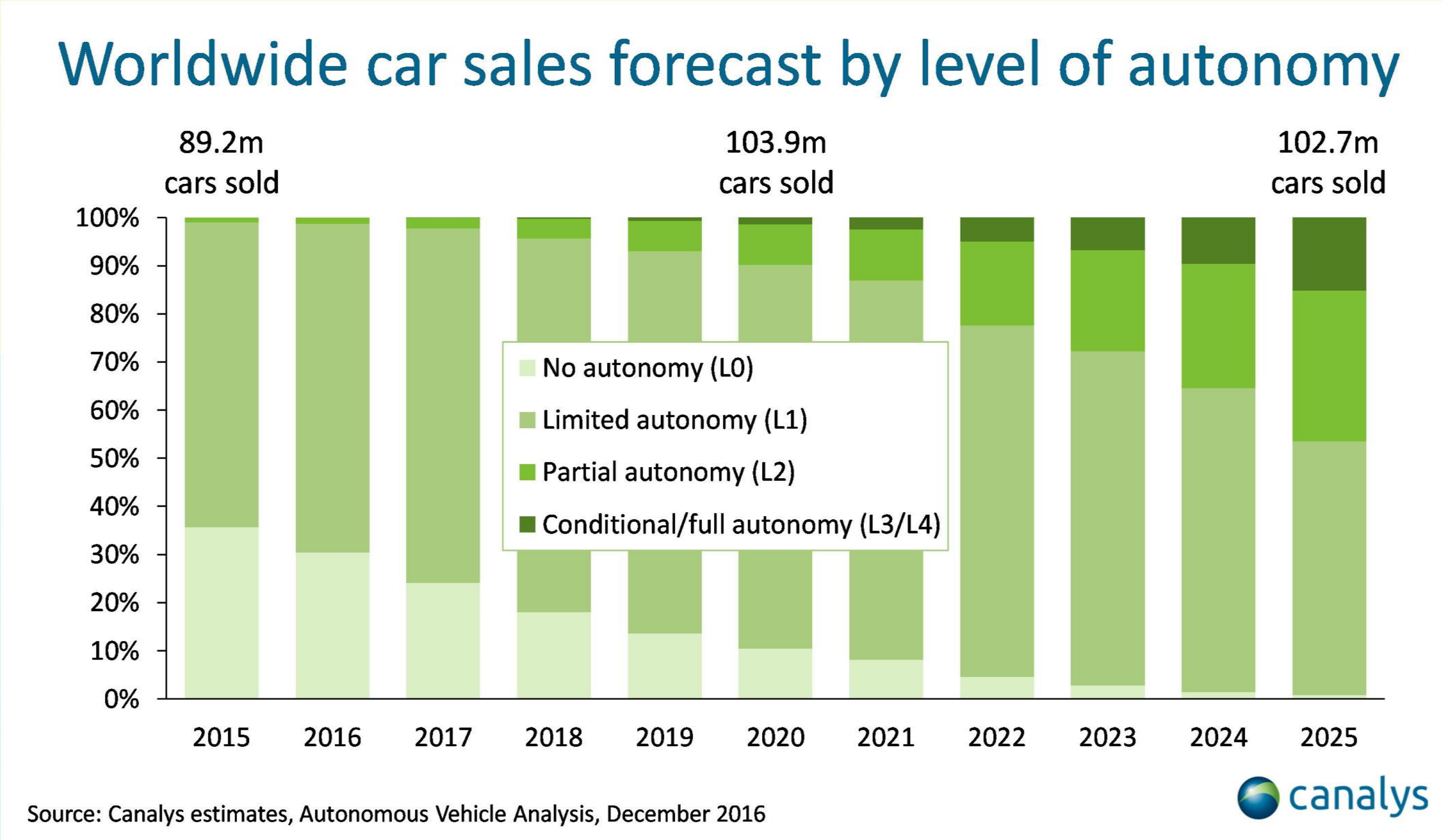
Examples of modern mobile CPS: smart wearables

A new wave of the information technology revolution has arrived that creates much more coherent and fit to use CPS and connects them to form the IoT

Importance of modern mobile CPS

- **Application areas of (mobile) CPS** cover ***virtually all socially important application sectors***, including:
  - *transportation and automotive*, e.g. traffic control, navigation, tracking, communication, mobile fares and personalized customer services, assisted/autonomous driving, etc.
  - *industrial, agriculture, safety, security and military applications*, e.g. robotics, mobile real-time in-the-field surveillance, monitoring, inspection, repair, assistance, etc.
  - *extension or replacement of human capabilities*, e.g. tele-operation, personal assistance, artificial limbs, implants, etc.
  - *social systems*, e.g. smart health-care and other numerous health-care applications, assisted leaving, law enforcement, public safety, military, etc.
  - *consummer applications*, e.g. mobile computing, communication, localization, navigation, gaming, entertainment, fashion, etc.
  - *commercial applications*, e.g. mobile inventory tracking and customer service, wearable augmented reality and other systems for touristic applications, and many others
- **The economic and societal importance of modern CPS is very high and rapidly increases**

Rapid growth of the mobile CPS and IoT markets



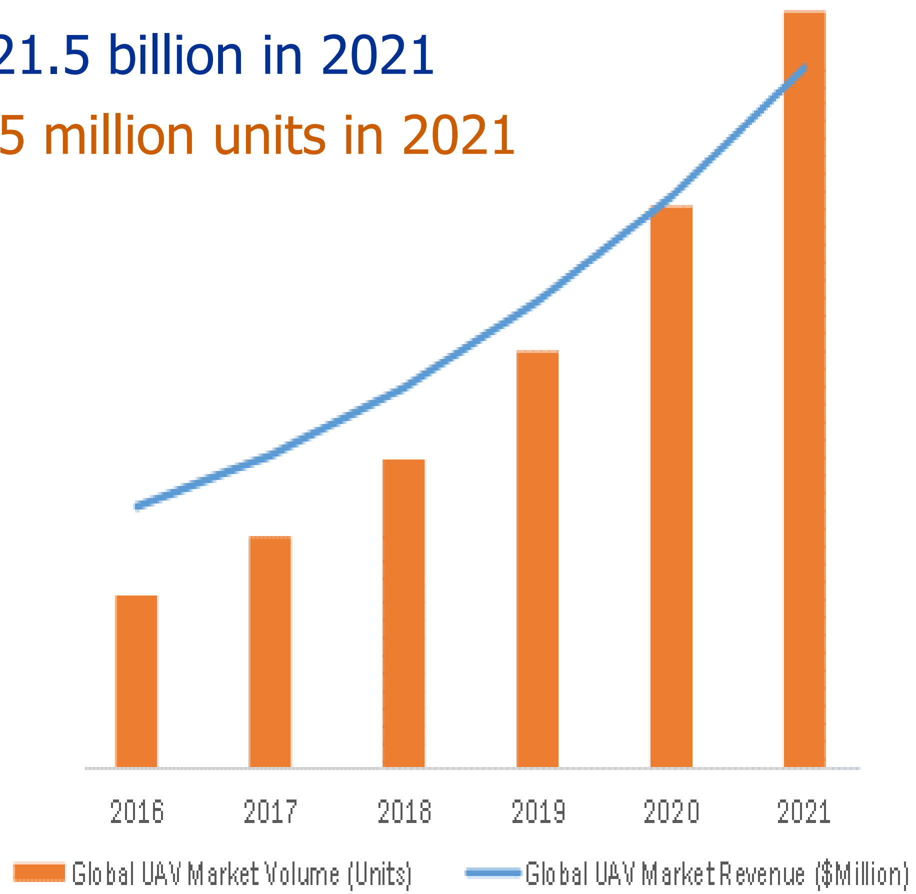
Rapid growth of the mobile CPS and IoT markets

Global unmanned aerial vehicle (UAV) market

$8 billion in 2016

$21.5 billion in 2021

>5 million units in 2021



- **The fastest growing market** of all mobile sectors is this **of smart wearable devices**:
  - $14 billion and 123 million devices in 2016
  - $34 billion and 411 million devices in 2020

  (CCS Insight, February 2016)

Source: BIS Research, January 2018

Challenges: unusual complexity and ultra-high demands

- The huge and rapidly developing markets of sophisticated mobile CPS represent **great opportunities**
- These opportunities come with a price of:
  - **unusual system complexity** and **heterogeneity**, resulting from ***convergence and combination of various applications and technologies*** in one system or even on one chip, and
  - **stringent and difficult to satisfy requirements** of modern applications
- **Smart cars, drones, robots and various wearable systems**:
  - involve **big instant data** from multiple complex sensors (e.g. camera, radar, lidar, ultrasonic, sensor network tissues, etc.) and from other systems, used for mobile vision, imaging, virtual or augmented reality, etc.
  - are required to provide **continuous autonomous service in a long time**
  - are **safety-critical**
- In consequence, they demand a **guaranteed (ultra-)high performance** and/or **(ultra-)low energy consumption**, while requiring a **high reliability, safety and security**

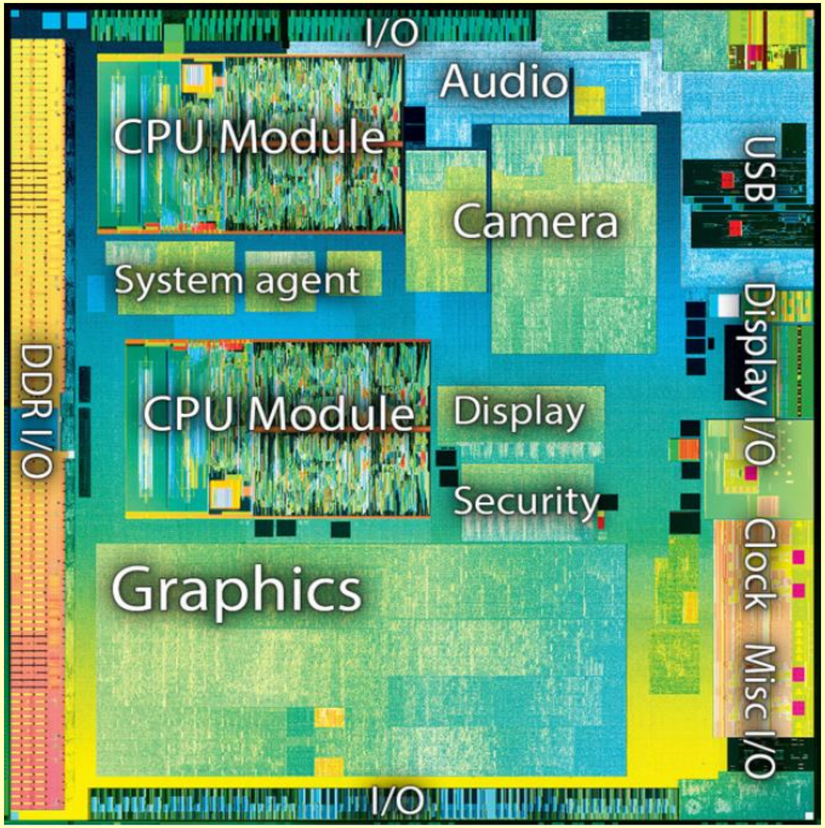
Challenges: application parallelism and heterogeneity

- The modern complex applications that require ultra-high performance and/or ultra-low energy consumption:
  - are from their very nature **heterogeneous**
  - include numerous different algorithms involving **various kinds of massive parallelism**: data parallelism, and task-level, instruction-level and operation-level functional parallelism

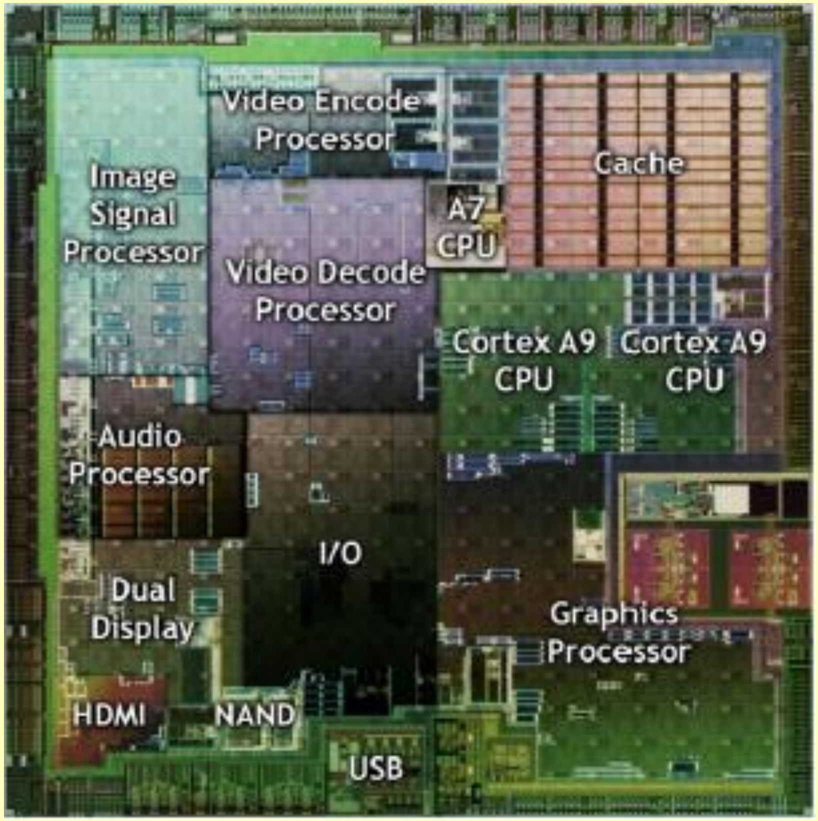
- To adequately serve these applications:
  - **massively parallel heterogeneous computation platforms** have to be exploited
  - multiple different or identical processors, each implementing a different part of a complex heterogeneous application and/or operating on a (partly) different data sub-set, have to work concurrently to realize the ultra-high throughput and ultra-low energy consumption

Challenges: application complexity, parallelism and heterogeneity

To implement the highly-demanding complex heterogeneous CPS applications ***complex heterogeneous MPSoCs*** *are needed*



Intel Atom Z3770*

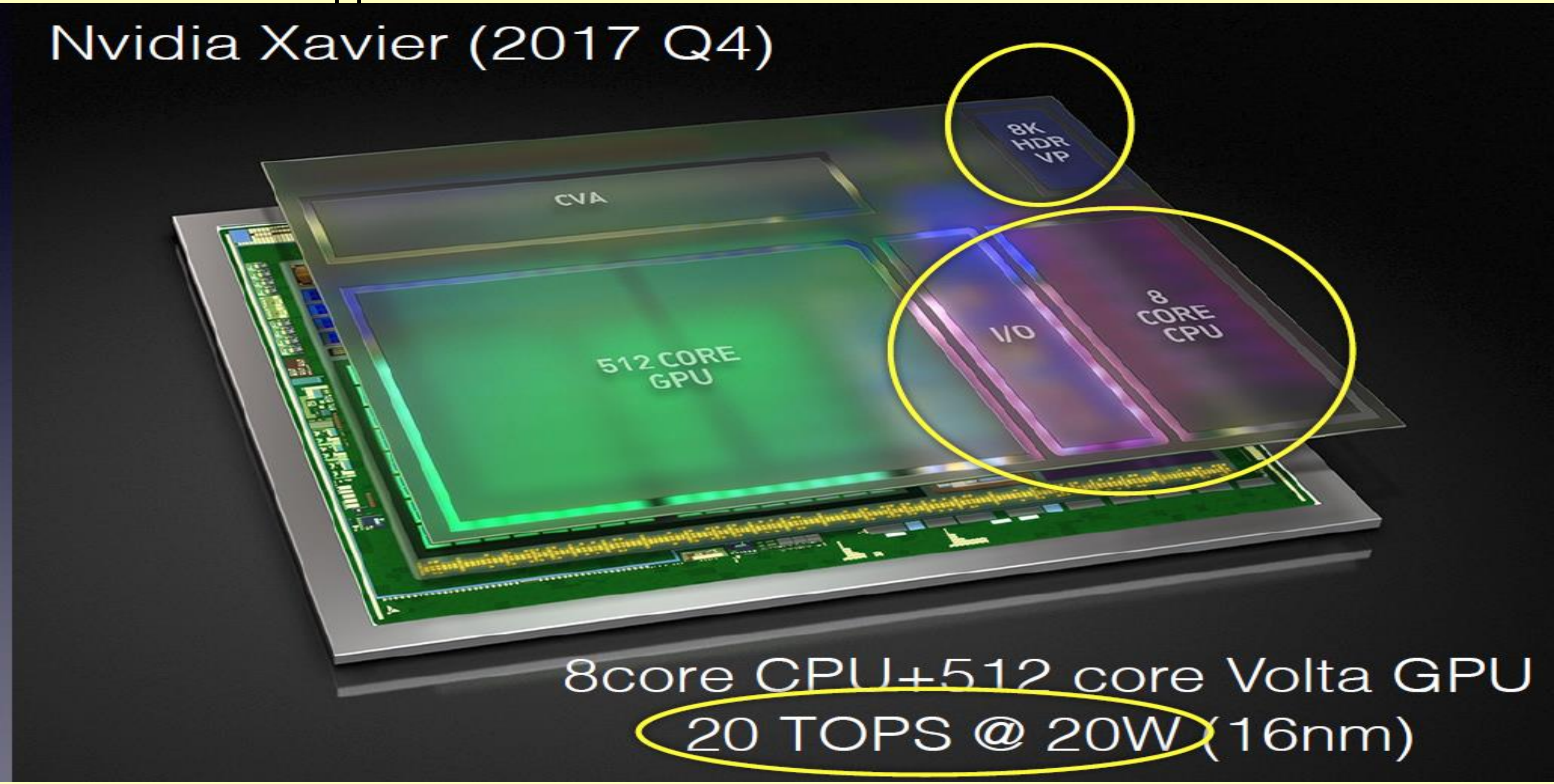


Nvidia Tegra 2⁺

*Source: http://tweakers.net/reviews/3162/2/intels-atom-bay-trail-de-eerstenieuwe-atom-in-vijf-jaar-zes-verschillende-bay-trails.html
⁺Source: http://www.anandtech.com/show/4144/lg-optimus-2x-nvidia-tegra-2-reviewthe-first-dual-core-smartphone/3

Challenges: application complexity, parallelism and heterogeneity

NVIDIA's advanced massively parallel heterogeneous MPSoC for ADAS and similar mobile CPS applications



Source: Albert Y.C. Chen, Viscovery

Challenges: distribution of intelligence, computing resources, services and workloads in the IoT chierarchy

- To transform the big data from multiple sensors to the information being directly used for decisions, while satisfying the stringent requirements of the modern mobile systems, a **careful distribution of information delivery and computation services among the different layers of IoT is needed**

- For many reasons of primary importance, as:
  - real-time availability of local information
  - guaranteed real-time reaction
  - security, safety, reliability
  - minimization of communication traffic and energy, etc.

  a majority of computing and decision making related to advanced CPS should be performed locally in the IoT edge devices, in collaboration among various local IoT edge devices or just above the edge nodes, and not in the higher levels of fog or in cloud

- The higher levels of fog and cloud should only be asked for services if:
  - necessary information or computing resources are not available locally, and
  - reaction-time, security, safety, etc. allow for this

Challenges: distribution of intelligence, computing resources, services and workloads in the IoT chierarchy

- This requires **implementation of advanced intelligent computations and sophisticated powerful embedded computing technology**:
  - **directly in the IoT edge devices** related to the complex sensors and actuators, or
  - **just above the edge nodes**, where the information from different sensors can be combined and based on the combined information the control decisions can be taken and subsequently actuated
- Sophisticated and powerful **edge computing** has to be used requiring advanced intelligence, processing power and communication capabilities to be pushed towards the edge-nodes of IoT, where the data originates and information is used (i.e. to sensors, controllers and actuators)
- A very good example of the edge computing necessity is the **local** vehicle-to-vehicle and -infrastructure communication and collaboration necessary for autonomous driving
- In consequence, the **IoT for advanced (mobile) CPS will be substantially different than Internet for other traditional targets**

Computing Technology versus Design Technology for CPS and IoT

- Many advanced processors and heterogeneous parallel MPSoC architectures have been proposed in the recent years
- Many of them are useful for various advanced (mobile) CPS applications
- **What is the problem?**
- The design methods and automated tools for:
  - mapping of complex heterogeneous parallel applications to such hardware platforms
  - modeling, analysis, development, verification, validation and certification of CPS involving combined diverse cyber and physical components or sub-systems
  - holistic development and multi-objective optimization of complex heterogeneous CPS
  - ensuring reliability, security and safety of critical CPS
  - development and management of autonomous evolvable distributed systems and systems-of-systems collaborating through IoT
  - management of competing CPS applications, computing resources, services and workloads in the IoT hierarchy

  are much less advanced

Quality-driven Model-based Design

- When considering a **system and design methodology adaptation** to the situation in the field of modern CPS, we have first to ask: *what general system approach and design approach seem to be adequate to solve the listed problems and overcome the challenges*?
- **Predicting the current situation,** more than 20 years ago I proposed such **system paradigm** and **design paradigm**, i.e. the paradigms of:
  - **life-inspired systems** and **quality-driven design**, and
  - the **methodology of quality-driven model-based system design** based on them
- From that time my research team and our industrial and academic collaborators were researching the **application of this methodology** to the design and design automation of embedded processors, MPSoCs and CPS, and this **research confirmed the adequacy of the quality-driven design methodology**
- For "*Outstanding Achievements and Contributions to Quality of Electronic Design*" I was awarded the Honorary Fellow Award by the International Society for Quality Electronic Design (San Jose, CA, USA, 2008)

Quality-driven Design, CPS and IoT for making high-quality systems

- In modern CPS sophisticated cyber systems (controllers) are tightly integrated with the controlled by them physical, social and life systems

- When using the quality-driven design methodology to develop the modern high-quality collaborating cyber-physical systems, we have a great chance to much better control and optimize the social, physical and life systems than till now

- ***With modern CPS and IoT technology we have a great chance to significantly improve systems used by us or that we are part of***

- **We also have no chance to not do this**

- ***Our social, physical and life systems have to be improved significantly and immediately***

- **Why?**

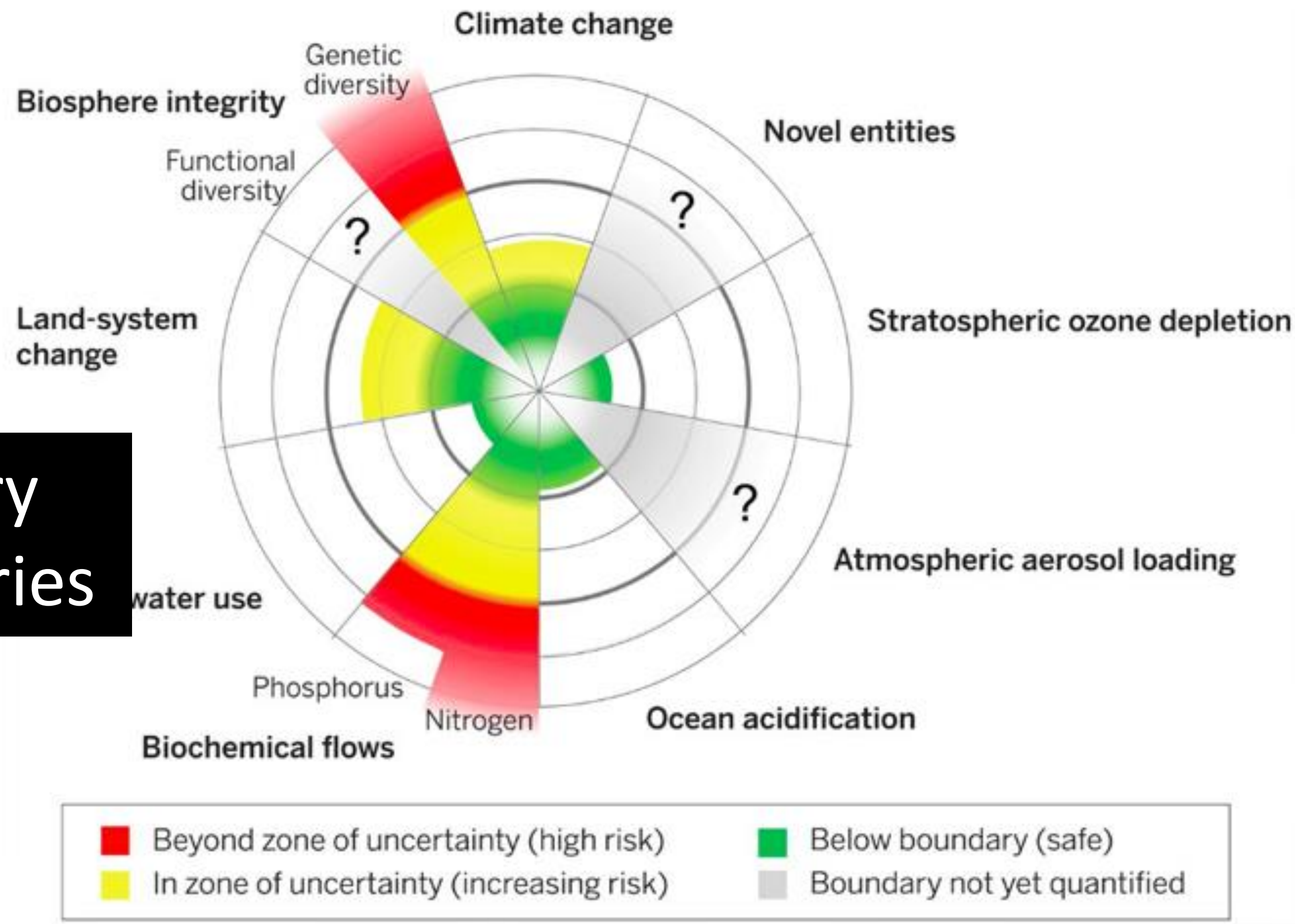
- Please watch the following few slides that I got from my friend Jean Paul Gueneau de Mussy, Sustainability Innovation Expert, CEO of Materials Innovation Company, https://materials-innovation.com/

Overall costs of Climate Change

Jean Paul GUENEAU DE MUSSY |

Jean Paul GUENEAU DE MUSSY |

Planetary Boundaries



Johan Rockström et all, February 2017, Volume 46, Issue 1, pp 4–17

Jean Paul GUENEAU DE MUSSY |

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Huge destruction, chaos, no care for long-term consequences

- These were only a few examples of what was done wrong for a long time with our social, technical and life systems on a global scale, and what resulted in a **huge destruction on a global scale**
- This huge destruction is a result of systemic drawbacks of the traditional economy and cumulation of bad decisions made by governments and companies only for a short-term profit, without adequately accounting for long-term consequences
- Example: the wild chaotic globalization, without carefully designed interfaces and collaboration between very different economic/political systems in different parts of the World and between companies from the very different systems
- Globalization is unavoidable, but it has to be well designed, regulated and controlled
- The not well regulated and not controlled inefficient collaboration chains and related material, product and waste flows of the wild globalization resulted in inefficient use of resources, environment destruction and pollution, climate change, bio-diversity loss, etc.

EUROPE Recognizes the CLIMATE and POLUTION CRISIS and starts to take serious measures

EU President **Ursula von der Leyen** unveiled Europe's "**Green Deal**" plan to fight the crises on Dec. 11, 2019

It represents a stepwise incremental approach to solve the problems

How to recover from the disaster?

- Covid-19 pandemics demonstrated the problems sharply
- Example: Due to globalization multiple supply chains became very complicated and very long, often crossing borders of several countries; due to Covid-19 pandemics many of these chains were broken or function inefficiently
- To recover from the disaster, ***a model of a well regulated and controlled effective and efficient system has to be applied to various kinds of systems, collaboration chains and related flows, implementing***:
  - **regenerative, circular and more local economy**

  and

  - **global ecology**
- ***What is circular regenerative economy?***

Traditional versus Circular Regenerative economy

- Traditional economy is characterised by assumption of unlimited growth; fierce competition; intensive exploitation of and fighting for non-renewable scarce resources; and short-term profit maximalization, without taking adequate care of the negative long-term economic, social and ecological consequences

- Traditional economy uses linear model: take non-renewable resources – make – use – dispose waste; it did not pay the actual costs of inefficient resource usage and of the pollution and destruction it made

- Circular regenerative economy is a systemic approach that aims to benefit all: business, society and environment, through:
  - quality-based growth, collaboration and partnership;
  - increasing use of renewable resources, resource sharing and gradually decreasing the use of non-renewable resources;
  - introducing biological cycles to regenerate living systems and technical cycles implementing product repair, reuse, sharing, remake, and recycling; and this way minimizing the use of scarce resources and regenerating the environment

Innovate applying circular economy and quality-driven design

- The principles of the circular regenerative economy are derived from the same source as the principles of my paradigms of life-inspired systems and quality-driven design
- They are derived from the observation of nature, and especially of structures and operations of living organisms, their populations and ecosystems that have demonstrated to effectively, efficiently and robustly work for many millions of years
- In relation to technical systems the principles of the circular regenerative economy are the same or similar as the main principles of the quality-driven design methodology proposed by me more than 20 years ago
- Circular regenerative economy and quality-driven design can be used together
- Large scale implementation of the circular regenerative economy will require **many breakthrough innovations of processes and products**
- All those innovations will have to be designed and implemented
- ***When designing and implementing the innovative processes and products the methodologies of circular regenerative economy and quality-driven design should be used***

Conclusion

- Systemic drawbacks of the traditional economy and cumulation of bad decisions made governments and companies without adequately accounting for long-term consequences resulted in the huge global environmental disaster
- To recover from the environmental disaster and further develop:
  - *a model of a well regulated and controlled effective and efficient system has to be applied to systems, collaboration chains and related flows*
  - *modern CPS and IoT technologies should be applied to much better control and optimize the social, physical and life systems than till now*
  - *methodologies of circular regenerative economy and quality-driven design should be used to design the systems*
- This presentation showed that innovations exploiting modern CPS and IoT technologies, circular regenerative economy and quality-driven design can significantly improve systems used by us or that we are part of
- The successive presentations will provide information on how to obtain funding, coaching and support for your cross-border Innovation Application Experiments