Research & Innovation on Advanced Computing

An EU Perspective towards Horizon 2020

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ICT Programme
European Commission
Motivation: Computing - a window of opportunity for Europe

On-going Framework Programme 7 research on Computing Systems – an overview

Research Challenges in Computing “at large”

New opportunities under FP7 Work Programme 2013 – first ideas

Towards Horizon 2020 - the FP for Research & Innovation 2014 - 2020
The Computing Spectrum

- Exascale
- Modernising & Scaling Applications
- Green low-cost data-centres
- Desktops
- Customised Computing
- High Performance Computing
- Mastering parallelism, virtualisation, concurrency, low power
- Computing with next generation fabrication technologies

Access for all through Clouds including for SMEs
Modular Computing Systems - a simplified view

Today’s advanced computing systems are composed of the following components or clusters thereof:

<table>
<thead>
<tr>
<th>Connectivity: fast ethernet vs proprietary</th>
<th>Complexity:</th>
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</thead>
<tbody>
<tr>
<td>➔ latency, bandwidth, hierarchies</td>
<td>• Heterogeneity</td>
</tr>
<tr>
<td><strong>GPU - accelerators for graphics and computing</strong></td>
<td>• Concurrency</td>
</tr>
<tr>
<td><strong>Multi-core / many-cores of traditional CPUs</strong></td>
<td>• Hierarchies</td>
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<tr>
<td><strong>Light processors</strong></td>
<td>• Energy/cost efficiency</td>
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<tr>
<td>low energy</td>
<td>• ...</td>
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<tr>
<td>low cost</td>
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Memory/storage: hierarchies

➔ cash, local, virtual, global, ...
Towards Horizon 2020: A window of opportunity for Europe

Fast paced evolution & disruptions in advanced computing

- Computing infrastructures rely on COTS more and more coming from the mobile & embedded world
- System SW increasingly becoming open source
- Energy efficiency as important as processing power
- Advanced computing resources accessible for new actors
  - Broad deployment of broadband
  - New business models, e.g. Cloud/pay-per-use based
- Knowledge mining is becoming a key enabler for industry
  - Applications becoming increasingly data-centric
  - Server farms, HPC, embedded computing converging

*Key challenge:* We need to master the complexity - concurrency, heterogeneity, hierarchies, cost, energy consumption!
Major Embedded Systems and Computing related activities under FP7

Focus of this speech

Activities:
- Research
- Policy
- Pilots
- Infrastructures
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A bottom-up approach building on EU strengths:
- Expand from successes in embedded & “mobile” computing
- Exploit EU expertise on “low energy– low cost”
- Profit from the convergence of the Computing worlds

Exploit synergies across the full computing spectrum
- Develop tools for mastering parallelism and concurrency
- Efficiently exploit multi- and many-core
- Customise heterogeneous nodes including GPUs, ... 
- Real-time, dependability, fault tolerance
- Master hierarchies of network connectivity and storage

Driven by needs of key industrial applications
FP7 Research on Computing Systems

Embedded computing
General purpose / data centers
HPC

2007
2009
2011

Total budget: 95 M€
MERASA: Multi-Core Execution of Hard Real-Time Applications Supporting Analysability

Key industrial partners: Honeywell, RAPITA

Achievements (ended 2010)

- Multi-core Architecture Design & Development
  - Based on multithreaded cores (Infineon-TriCore, ESA-LeonCore)
  - Prototype available as simulator and on FPGA
  - Hard real-time support - capable of mixed application execution

- Worst Case Execution Time Tools, System SW & Application
  - Static tool Otawa adapted to MERASA processor
  - Measurement-based RapiTime tool instrumentation for multi-core
  - WCET Coding guidelines for multi-core execution developed
  - Posix-compliant system software with thread isolation
  - Parallel hard real-time task on quad-core FPGA was WCET-analysed

Successor Project parMERASA (under negotiation):
- Parallelise hard real-time applications
- Industrial users: Bauer Maschinen, Denso Automotive

www.merasa.org
CRISP outcome
- Scalable, reconfigurable, self-repairing many-core platform
  - IP cores, Network-on-Chip, run-time system, tooling, applications
- Well balanced: Power, Programmability, Performance & Price
- Proficient for embedded digital signal stream processing

Expected impact
- Increased market share of inexpensive generic platforms
- European excellence in forthcoming streaming applications
  - Both low-cost consumer and demanding professional applications
- Mastering new powerful reconfigurable computing platforms

www.crisp-project.eu
eMuCo: Embedded Multi-Core Processing for Mobile Communication Systems

Key industrial partners: Infineon, ARM, Telelogic (IBM)

The trend: Future mobile broad-band (LTE/4G) will offer substantial higher data rates increasing computational performance requirements for mobile devices

**The eMuCo Solution:** \((\text{MCP} + \text{LPC}) \times F = \text{MC} \times V\)

(More Computational Performance + Low Power Consumption) x Flexibility = MultiCore x Virtualisation

**Major Achievements (ended 2010)**

- Sustained leadership in mobile platforms
  - Project referenced directly by leading manufacturer (INF)
  - Big/Little core concept considered for ARM product roadmap
  - Positioning for market leadership in mobile/tablet multi-core systems
- Leadership in software development tools for mobile multicore systems
- Open source platform components for European mobile systems

www.emuco.eu
• Project Driver
  – Power consumption of the server chip and DRAM

• Project Goal
  – 10x efficiency in server chip level power consumption

• Three Major Objectives
  – Investigation of Power Reduction techniques in server chips
  – Characterizing Server Workloads on ARM-based low-power Servers
  – Server Chip Reliability and Fault Tolerance

www.eurocloudserver.com
EU Research on Computing Systems: Some Industrial Success Stories

- **ARM**
  - ARM processor used in 95% of the world’s mobile handsets
  - Early beneficiary of OMI (OMI-MAP)
  - Participation in 30 projects in 20 years
  - From 162 employees in 1996 to 1900 in 2009
  - Energy-efficiency trend positions ARM broadly on computing market

- **CAPS**
  - Leading global provider in compiler technologies & engineering services for parallel hybrid computing
  - Participation in EU project Milepost crucial for success of building a market leader product
  - Triplication of staff in 4 years

- **TTTech**
  - Market leader in time-triggered safety critical real-time networks
  - Supported by 9 EU projects
  - From spin-off to 200 employees in 12 years
Research relevant for data centres: a broad FP7 ICT view

- Data centre servers
  ICT-Challenge 3
  - Eurocloud
  - IOLANES
  - RELEASE
  - ...

- Green Data Centres
  ICT Challenge 6
  - FI4Green
  - GAMES
  - ...

- Cloud Computing
  ICT-Challenge 1
  - Reservoir
  - CONTRAIL
  - 4CAAST
  - ...

- Towards Exa-scale HPC
  ICT-Challenge 9 - FET
  - MontBlanc
  - DEEP
  - CRESTA
  - ...

European Commission Information Society and Media
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Convergence of application worlds ➔ convergence of computing worlds

The engineering world
- engineering
- creative design
- compute-intensive
- performance

The management services world
- RRP (res requ plan)
- logistics
- data-centric
- database transactions

The physical world
- embedded systems
- sensor networks / IoT
- real-time
- dependable & reliable

The Future - Converging Worlds
- forecasting/decision support
- from db/appl/web servers to “emergence of services”
- data centric, storage unlimited
- all-in-memory
- computing continuum
- systems of systems
- real-time,
- dependable, reliable
- accessibility anywhere anytime
- energy efficiency

Life Science

Social Networks
Crowd Sourcing

Finances
Industrial Application Pull: a Key Driver for Computing

Example: Computing & Engineering

- Engineering - a key driver for the European economy
- Successful European products: innovative, high quality at competitive prices
- The full spectrum of Advanced Computing: a key enabler for quality, innovation and efficient production
Where & how should Europe invest?

- Market-driven forces along the value chain
- Need for a comprehensive approach
  - involving all relevant actors
  - visionary industry in the driving seat
  - research, development, piloting, prototyping (complementary funding)
    - Manufacturing of components & systems?
    - System integration (HPC, server farms,...)?
    - Prototyping systems & services (e.g. PCP)?

- Balance technology push and application pull
  - The bottom-up HW and system perspective
  - The top-down software & services perspective
Computing systems: Research challenges ahead
The HiPEAC Vision 2011/1012
Technology-scalable data centers: Challenges and recommendations

Medium Term Research Challenges:
- Mobile platform efficiency in server nodes
- Taming the data deluge
- Holistic integration
- Federated data centers

Longer term priorities
- Specialised HW for servers
- Probabilistic servers
- Computing with renewable energy
- DC everywhere – global scale federation
Strategy for R&I through HPC: Key challenges and research issues

- Technologies:
  - Computing must become more energy efficient
  - Multi/mnaycore and heterogeneous systems must be mastered
  - Robust and reliable real-time HPC is required
  - Application developer productivity to match enterprise computing

- Applications:
  - New methods in simulation exploiting massive parallelism
  - Industrial HPC applications to be integrated in workflows
  - Applications become increasingly data-intensive

- Accelerating Take-up:
  - Encouragement of SMEs
  - New access and business models
  - Migration pathways for legacy applications
  - Encourage innovation by independent software vendors
  - Raising awareness of the changing technology landscape
  - Break dependence on dual expertise – HPC and application
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First reflections related to Computing Systems under WP2013

- Next generation of energy efficient servers:
  - Integration of components, prototyping, validation/benchmarking

- Exploit synergies between computing disciplines:
  - Expanding on European strengths

- New platforms addressing mixed criticalities
  - Exploring where embedded systems meet the Internet

- Stimulate industrial take-up of novel computing tools

- Constituency building, roadmapping:
  - E.g. new programming models, algorithms, programming languages, abstraction models, tools to better master parallelism, hierarchies of storage and connectivity, heterogeneity, energy consumption, ...

- Piloting how to bring HPC-Cloud-based simulation services to the fingertip of SMEs
  - Focus on engineering and manufacturing (PPP Factory of the Future)
Next generation of energy-efficient servers for data-centers

- Datacenters are the cornerstones of the cloud.
- Europe is strong on technologies relevant for the next generation of energy-efficient servers for data-centers
  - Building on its strengths in mobile & embedded computing
  - Energy-efficiency, dependability, time-criticality, ...
- Should Europe increase ambitions in datacenter R&I?
  - Address in an integrated way the complete European datacenter eco-system (processor, chip, board, rack, storage, network, system software, apps)
  - Target 100x improvement in cost- and energy-efficiency
  - Develop small-scale but full functional data-center prototypes
Synergies across all computing disciplines

- Energy efficiency
- Dependability
- Time-criticality
- Parallelisation – manycore, GPUs
- HW/SW co-design
- Customisation - heterogeneity
- Virtualisation
- Reconfigurability
- Multi-stacking / optical interconnect

Stimulate silo-like constituencies to network and build on each others strengths.
## Mapping: Application/data parallelism ↔ Computer system parallelism

### Natural parallelism in engineering: operations and data

- **Business processes**
- **Multiphysics/ multiscale / coupling of disciplines**
- **Parameter studies / stochastic models within disciplines**
- **Partitioning of block-structured or unstructured meshes**
- **Threading for many-core shared memory**
- **Vector/ matrix Operations**

### High level specification languages/tools

- **Abstraction**
- **More automatic**
- **Decouple application from programming expertise**

### Hierarchy of parallelism in HPC clouds incl. hierarchies of memory & connectivity

- **The Cloud**
- **Heterogeneous HPC systems**
- **Clusters of homogeneous nodes**
- **Nodes with several processing elements**
- **Many core threading**
- **SIMD Operations**

**Engineering**
Bringing HPC-Cloud-based simulation services to the fingertip of engineering/manufacturing SMEs

- SME first-time users of simulation codes
- Innovation centres/clusters
- Application experts
- Established simulation code providers
- Cloud and parallelisation experts
- Commercial cloud providers
- HPC resource providers

Pan-European «Cloud» of HPC Resources

User 1 → ISV → Provider(s)
User 2 → ISV → Provider(s)
... → ISV → Provider(s)

Brokering / dissemination / exploiting synergies
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Horizon 2020

- Commission proposal for a research and innovation funding programme (2014-20)
  - €80 billion in constant 2011 prices (~€90 billion in current prices)
  - For decision by European Council, Parliament by end of 2013
- Part of proposals for next EU budget, complementing Structural Funds, education, etc.
- A core part of Europe 2020, Innovation Union & European Research Area:
  - Responding to the economic crisis to invest in future jobs and growth
  - Addressing peoples’ concerns about their livelihoods, safety and environment.
  - Strengthening the EU’s global position in research, innovation and technology
What’s new?

- **A single programme** bringing together three separate programmes/initiatives (FP7, CIP, EIT)
- **More innovation**, *from research to retail, all forms of innovation*
- **Focus on societal challenges** facing EU society, *e.g. health, clean energy and transport*
- **Simplified access**, *for all companies, universities, institutes in all EU countries and beyond.*
Horizon 2020
Objectives and structure

Europe 2020 priorities

Tackling Societal Challenges
- Health, demographic change and wellbeing
- Food security and the bio-based economy
- Secure, clean and efficient energy
- Smart, green and integrated transport
- Supply of raw materials
- Resource efficiency and climate action
- Inclusive, innovative and secure societies

EIT and JRC will contribute to addressing these challenges

Creating Industrial Leadership and Competitive Frameworks
- Leadership in enabling and industrial technologies
- Access to risk finance
- Innovation in SMEs

Excellence in the Science Base
- Frontier research (ERC)
- Future and Emerging Technologies (FET)
- Skills and career development (Marie Curie)
- Research infrastructures

Simplified access

Common rules, toolkit of funding schemes

International cooperation

European Research Area

• ICT
• Nanotechnologies
• Advanced Materials
• Biotechnology
• Advanced Manufacturing
• Space

tentative - current status of discussion
Horizon 2020
Enabling and industrial technologies

- Strategic, technology focused approach
  - With potential applications in many sectors/ challenges

- Differentiated from:
  - Societal challenges: demand led, combining different technologies/ solutions
  - European Research Council: Bottom up

- A new generation of components and systems: engineering of advanced and smart embedded components and systems
- Next generation computing: advanced computing systems and technologies
- Future Internet: infrastructures, technologies and services
- Content technologies & information management: ICT for digital content and creativity
- Advanced interfaces and robots: robotics and smart spaces
- Micro- and nanoelectronics and photonics
Common message of ISTAG and HLG KET

- End-to-End value chain from R&D & innovation in ICT needed

The "three pillars bridge" to pass across the "valley of death"

- Special for ICT:
  + Services
  + Systems

Ways towards sustainable competitiveness in ICT
Manufacturing
Deployment in EU-wide services and platforms
Joint pre-commercial procurement of complete systems to address societal challenges

Source: High Level Group on Key Enabling Technologies
Conclusions

- ICT theme of “Leadership in enabling and industrial technologies” in H2020 includes:
  - Next generation computing: advanced computing systems and technologies
- Innovation measures bridging between research and the market key under H2020
- EC is preparing FP7 WP 2013: new opportunities for computing research
  - Tentative WP publication: July 2012
  - Two Calls considered: closing early 2013
  - Including transition measures
- Consultations with experts to define the detailed content of H2020 continue

More information:
Horizon 2020: www.ec.europa.eu/research/horizon2020