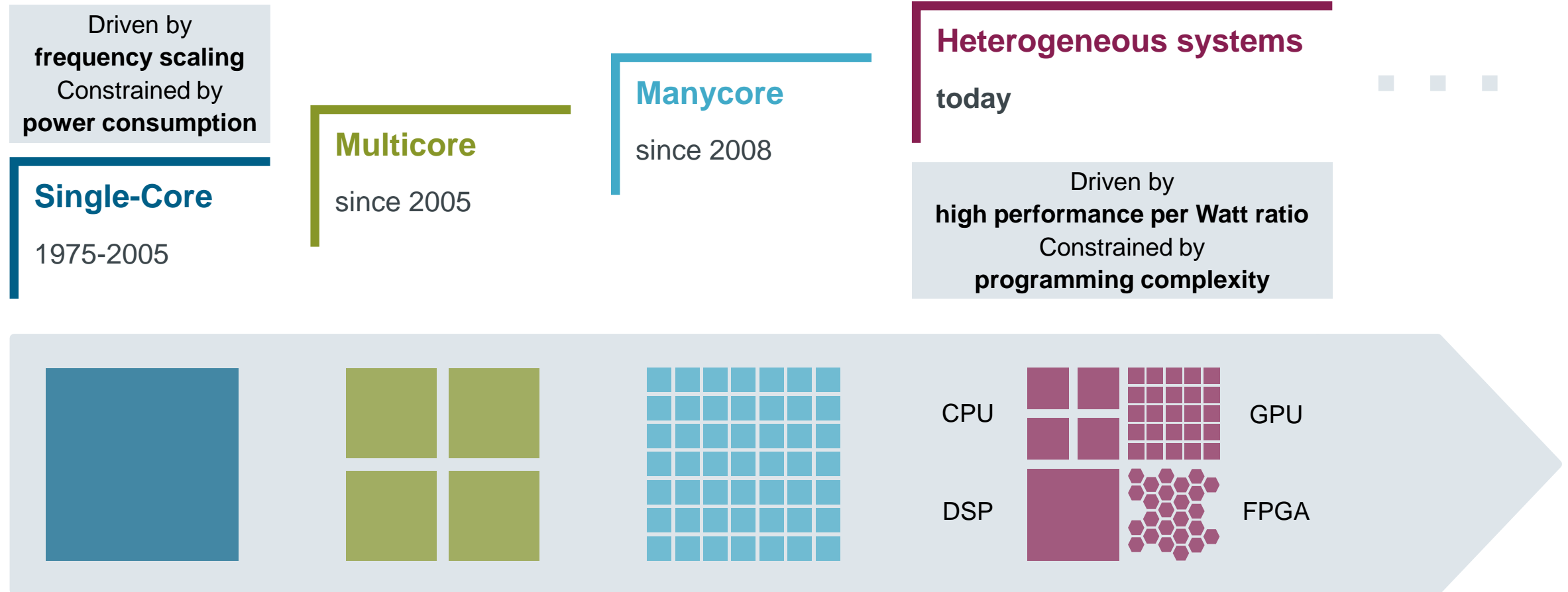


# Parallel Programming of Heterogeneous Embedded Systems

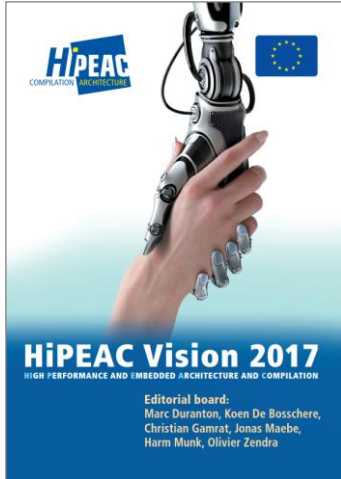
MTAPI and EMB<sup>2</sup> in Action

# Hardware Trends – From Single-Core Processors to Heterogeneous Systems on a Chip



H. Esmailzadeh et al., "Dark silicon and the end of multicore scaling", International Symposium on Computer Architecture (ISCA). ACM, 2011.  
M. Zahran, "Heterogeneous Computing Here to Stay". ACM Queue, Nov/Dev 2016.

# Continuing Growth of Heterogeneous Systems

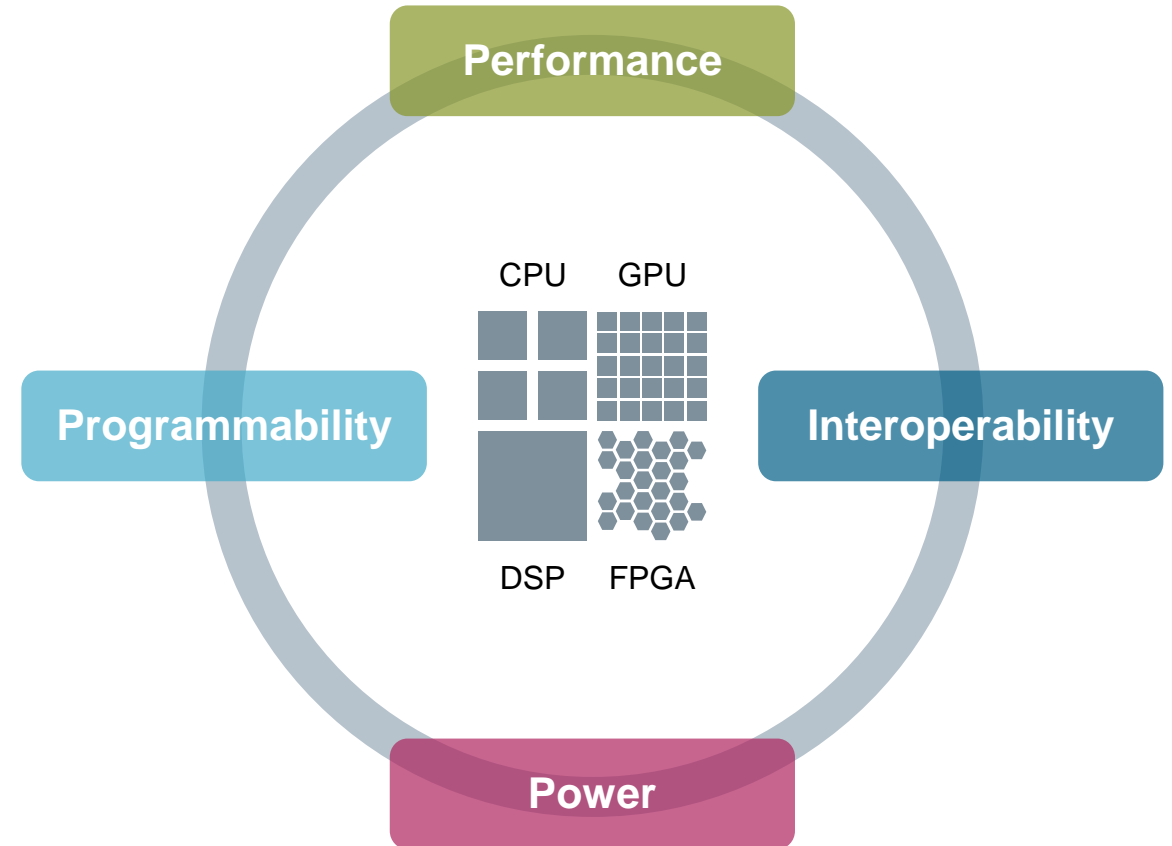


“Heterogeneous systems provide an effective way of responding to the ever-increasing demand for **more computing power**. However, ensuring **interoperability** and **programmer productivity** is a significant challenge.”

Low-power scalable heterogeneous architectures and their programming belong to the **top challenges until 2022**.

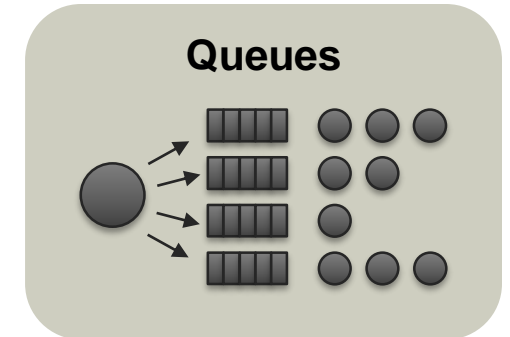
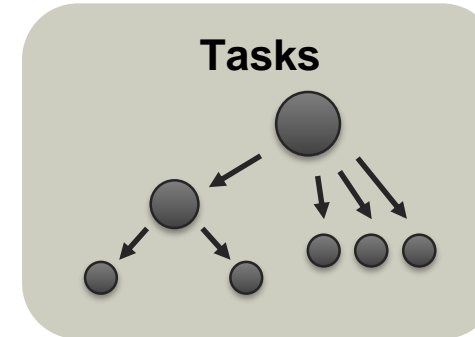
<https://www.hipeac.net/publications/vision/>

<https://www.computer.org/cms/ComputingNow/2022Report.pdf>



# Multicore Task Management API (MTAPI)

<http://www.multicore-association.org/workgroup/mtapi.php>

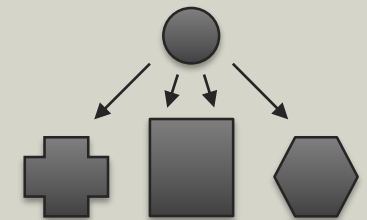


## MTAPI in a nut shell

- **Standardized API** for task-parallel programming on a wide range of hardware architectures
- Developed and driven by practitioners of **market-leading companies**
- Part of the Multicore Association's **ecosystem** (MCAPI, MRAPI, SHIM, ...)

## Heterogeneous Systems

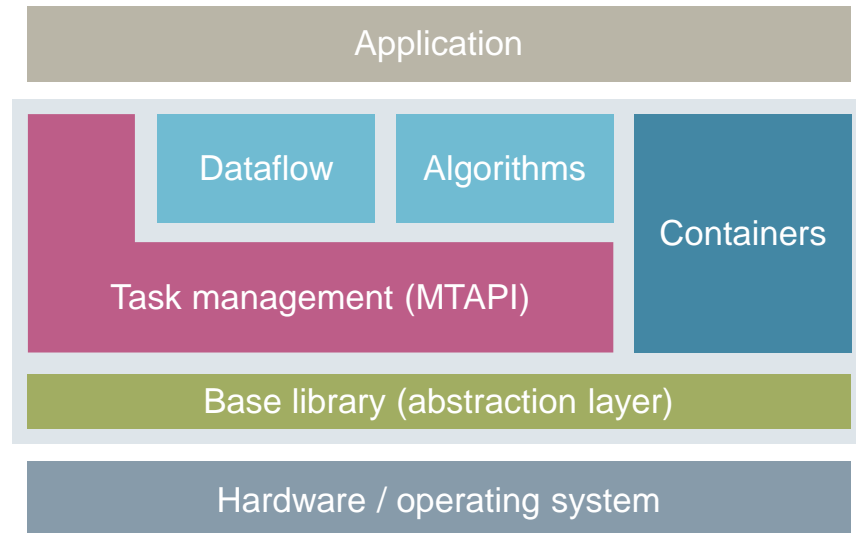
- Shared memory
- Distributed memory
- Different instruction set architectures



# Embedded Multicore Building Blocks (EMB<sup>2</sup>)

<https://embb.io/>

EMB<sup>2</sup> is an open source C/C++ library that provides generic building blocks for compute-intensive applications.



## Key features and requirements:

- Based on **MTAPI industry standard**
- Easy parallelization of **legacy code**
- Support for **real-time** applications (task priorities / affinities, lock-free data structures)
- **Resource awareness** and **determinism** (no dynamic memory allocation during operation)
- **Portability** on a variety of hardware architectures



# Sample Application Areas

## Sensing, Imaging, and Signal Processing

Process complex sensor data to track the environment



## In-field Data Analytics and Internet of Things (IoT)

Analyze large amounts of data on the devices in real-time



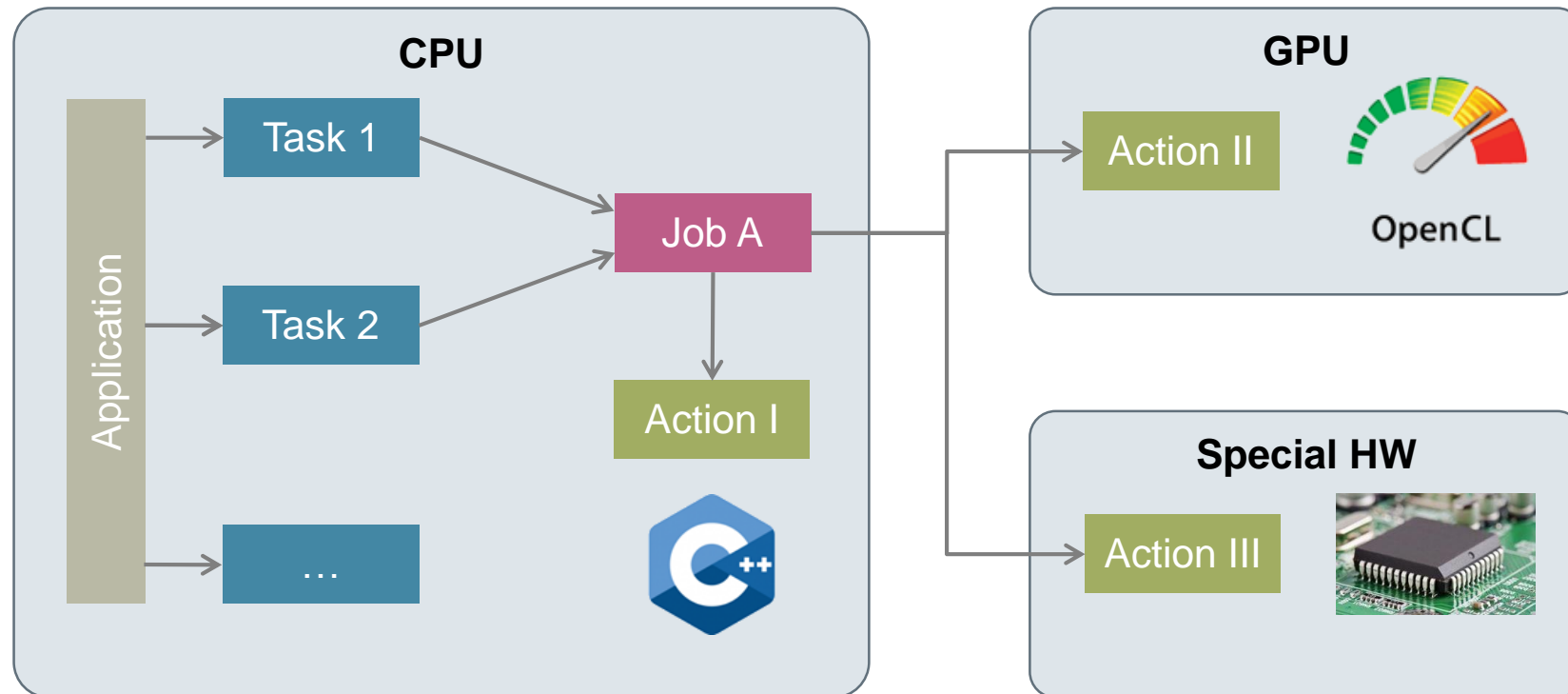
## Simulation and Augmented Reality

Efficiently combine the physical world with virtual ones



# MTAPI Programming Model – Jobs, Actions, and Tasks

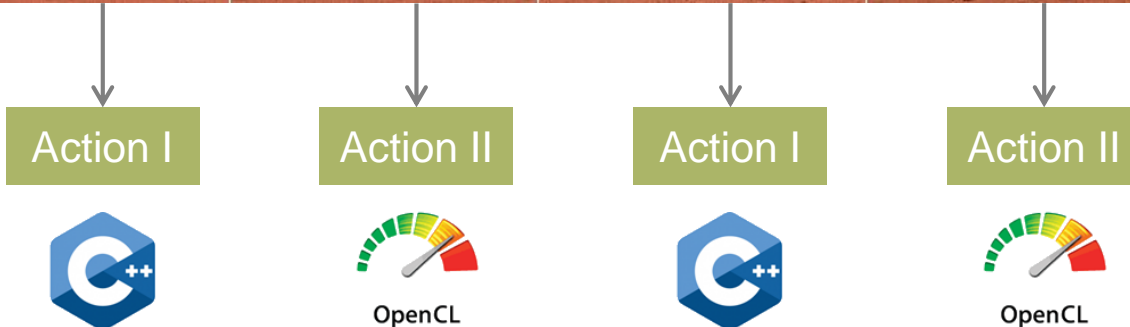
- **Job:** Piece of work with a unique identifier
- **Action:** Implementation of a job (hardware or software-defined)
- **Task:** Execution of a job with some data to be processed



# Programming Heterogeneous Systems (Example)

Apply a digital filter to a sequence of images utilizing CPU and GPU.

Pitcher's motion, Cincinnati Reds, 9/15/2004, by Rick Dikeman; Source: [English Wikipedia](#); CC BY-SA 3.0



1. Create Job (`job_filter`)
2. Create Action I (CPU) associated with `job_filter`
3. Create Action II (GPU) associated with `job_filter`
4. Apply `job_filter` to each element of a given range:

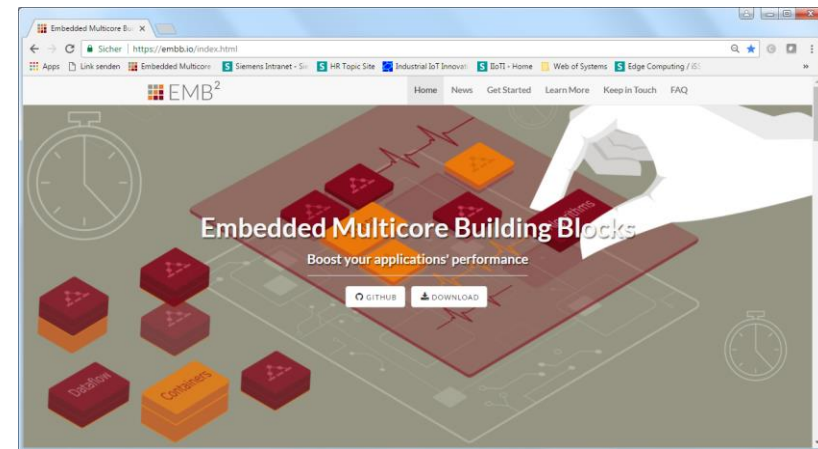
```
emb::algorithms::ForEach(  
    range.begin(), range.end(),  
    job_filter);
```

Alternatively, use dataflow networks for processing continuous streams of data.



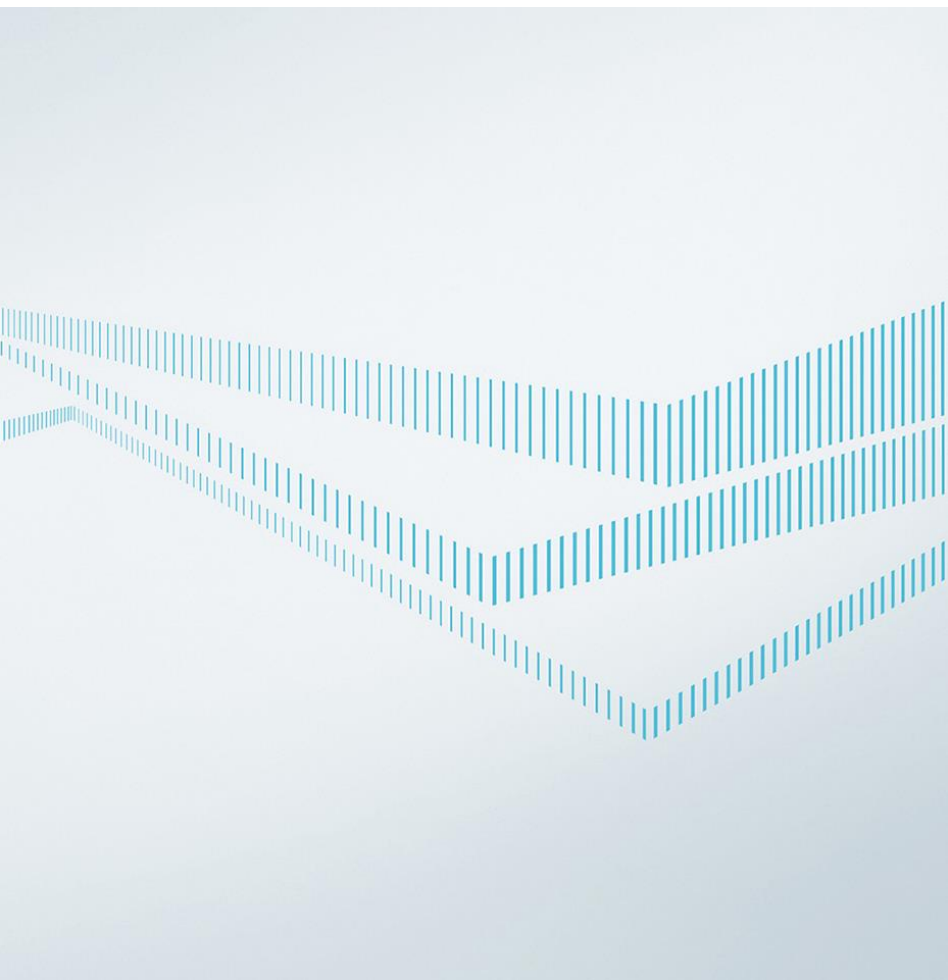
# Summary and Conclusion

- Software developers will be expected to enable single applications to exploit **large number of cores that are increasingly diverse**.
- MTAPI specifies **standardized interfaces** for leveraging the performance of such heterogeneous systems.
- The Embedded Multicore Building Blocks (EMBB<sup>2</sup>)
  - provide a **fully compliant MTAPI implementation** plus C++ wrappers for convenient task management,
  - ship with **ready-to-use plugins** for OpenCL, CUDA, and distributed systems communicating over network,
  - help to increase **developer productivity** through high-level patterns and parallel algorithms,
  - are specifically **designed for embedded systems** and the typical requirements that accompany them.



<http://www.multicore-association.org/>  
<https://embb.io/>

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