HiPEAC, Bologna – 22 January 2020

CERBERO Scientific Highlights

Innovation on Models of Computation and Architecture

INSA-UPM-UNISS Contributions

Horizon 2020
European Union funding
for Research & Innovation

Innovation on Dataflow MoCs

Model of Computation

a.k.a. programming paradigm

Definition:

- Set of operational elements that can be composed to describe the behavior of an application.

→ **Semantics of the MoC**

Objective:

- Specify implementation-independent system behavior.
- Ease specification, (parallel) implementation, and verification of system properties.

How:

- MoCs act as the interface between computer science & mathematical domain.

Innovation on Dataflow MoCs

- **CERBERO Tools are Model-Based from the Start**

	Dataflow MoCs								
	SDF	PiSDF	KPN	DPN	PN	RTL	DES	SCE	TS
MECA								✔	
VT									✔
DynAA			✔		✔		✔		
AOW	✔								
PREESM	✔	✔							
SPiDER		✔							
PAPIFY		✔		✔					
JIT HW						✔			
ARTICo³		✔				✔			
MDC	✔	✔		✔		✔			

Table from D3.2 – Models of Computations

Innovation on Dataflow MoCs

Innovation Drivers: CERBERO Requirements

- Increase the level of abstraction for HW/SW co-design.
- Support cross layer interoperability between tools.
- Foster performance-aware design (KPI-based).
- Provide development tools for adaptive systems.

What's new from CERBERO?

- Dataflow Extension for Persistent State Representation
- Modeling Periodic Real-Time Constraints in the SDF Model
- PiSDF MoC Extension through Polyhedral Transformations
- Numerical Representation of Directed Acyclic Graphs
- Models of Architecture

Innovation on Dataflow MoCs

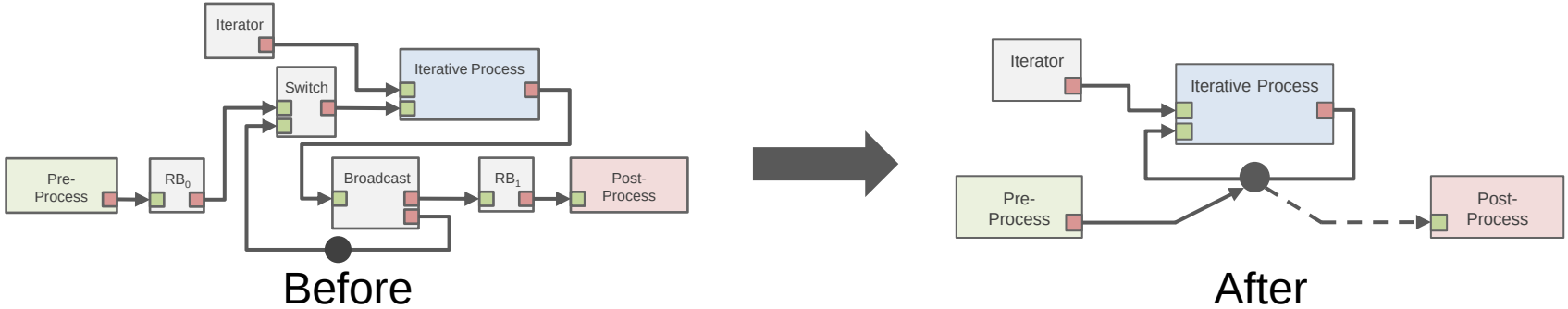
Dataflow Extension for Persistent State Representation

Motivation: Persistent State Specification

- Poorly captured by stream-processing MoCs.
- Indispensable for computer vision or machine learning.

Contribution: Meta-Model for Dataflow MoCs

- Extends semantics with explicit delay initialization & hierarchical persistence.

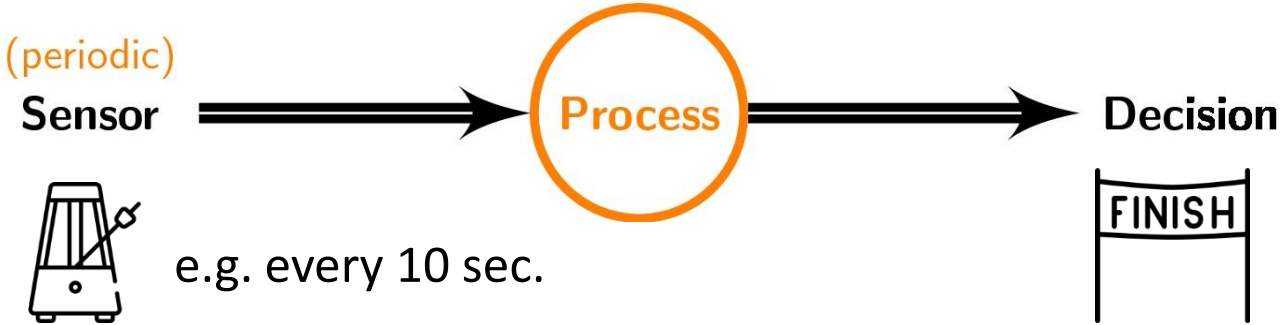


Innovation on Dataflow MoCs

Modeling Periodic Real-Time Constraints in the SDF Model

Motivations:

- Needed for KPI-oriented design.
- Needed for real-time CPS design with fixed sensor sampling rates.



Contribution:

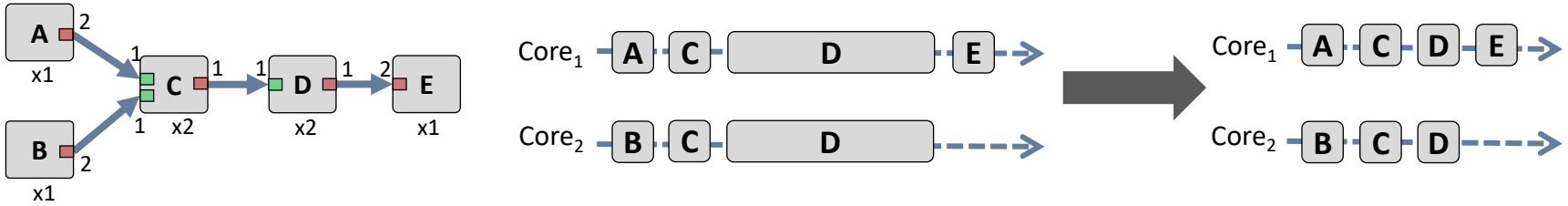
- Semantics for specifying periodic constraints for some dataflow actors of a graph.
- Necessary conditions for checking constraints validity and schedulability.
- Scheduling algorithm enforcing the specified constraints.

Innovation on Dataflow MoCs

PiSDF MoC Extension through Polyhedral Transformations

Motivations: Intra-actor optimization

- Missed optimization opportunities in compute-intensive codes



Contribution: Extension of APOLLO to PiSDF MoC

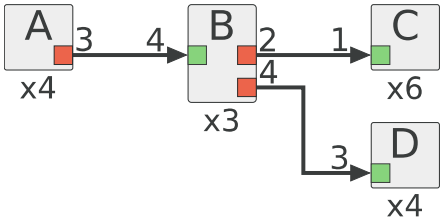
- APOLLO is a compiler framework to optimize compute-intensive codes through polyhedral transformations (data locality, data independency)
- APOLLO-multiversioning tries several transformations and selects the best one
- Each actor can be optimized independently
- Integrated with PREESM and SPiDER to exploit intra-actor optimizations

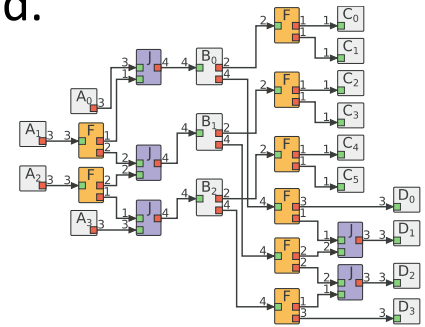
Innovation on Dataflow MoCs

Numerical Representation of Directed Acyclic Graphs (DAGs)

Motivations: Overheads of DAG management for scheduling

- SDF to DAG conversion make data parallelisms and task dependencies explicit.
- Important computational and memory overhead.





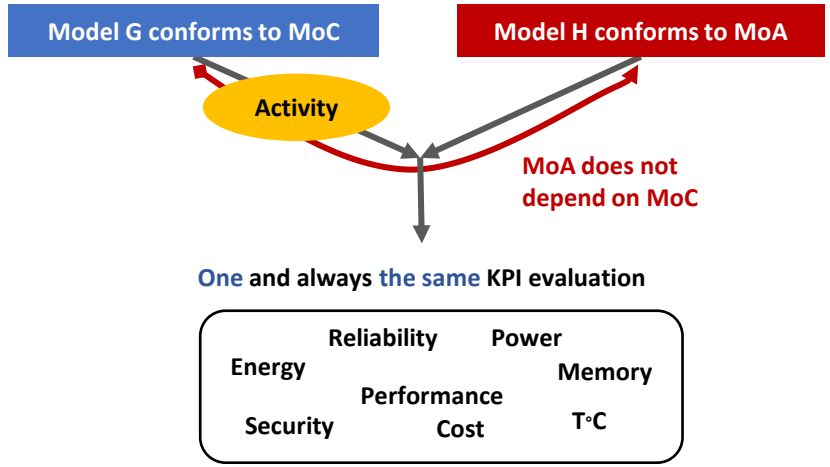
Contribution: On-the-fly DAG information computations

- Computed whenever needed during the runtime mapping/scheduling process.
- Numerical representation vs DAGs
  - Memory usage reduced by at least 94%
  - Scheduling time reduced by at least 47%

Innovation on Models of Architecture (MoA)

MoC-like abstractions of sub-systems interactions and bottlenecks

Motivations: performance evaluation should be repeatable and portable between tools



Contribution: State of the Art and defined properties of MoAs

- Proposed the linear LSLA model of architecture, and the notion of *activity*.
- Demonstrated energy modeling of a complex SoC with 86% fidelity

Innovation on Dataflow MoCs and MoAs

- **Selected Publications from CERBERO on MoCs and MoAs:**
  - Arrestier, F.; Desnos, K.; Juarez, E.; Menard, D. *"Numerical Representation of Directed Acyclic Graphs for Efficient Dataflow Embedded Resource Allocation"* Transactions on Embedded Computing Systems - EMSOFT Proceedings, 2019.
  - Honorat, A.; Desnos, K.; Pelcat, M.; Nezan, J.-F. *"Modeling Nested For Loops with Explicit Parallelism in Synchronous Dataflow Graphs"* International Conference on Embedded Computer Systems: Architectures, Modeling, and Simulation (SAMOS), Pythagorion, Greece, 2019
  - Arrestier, F.; Desnos, K.; Pelcat, M.; Heulot, J.; Juarez, E.; Menard, D. *"Delays and States in Dataflow Models of Computation"* International Conference on Embedded Computer Systems: Architectures, Modeling, and Simulation (SAMOS), Pythagorion, Greece, 2018
  - Desnos, K.; Palumbo, F. *"Dataflow Modeling for Reconfigurable"* Chapter of Handbook of Signal Processing Systems 3rd Edition. Springer, 2018.
  - Pelcat, M., Mercat, A., Desnos, K., ... & Bhattacharyya, S. S. " Reproducible evaluation of system efficiency with a model of architecture: From theory to practice ". IEEE TCAD, 37(10), 2017.
  - Pelcat, M. *"Models of architecture for DSP systems"* Chapter of Handbook of Signal Processing Systems 3rd Edition. Springer, 2018.
  - … and more to come.
- **Open-source implementations:**
  - **All listed contributions are publicly available within the open-source components of the CERBERO toolchain.**

Additional slides