

#### A runtime adaptation tool for cyber-physical systems

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# A Runtime Adaptation Tool for Cyber-Physical Systems modeled by a dataflow MoCC Guillaume Roumage<sup>1</sup>, Selma Azaiez<sup>1</sup>, Stéphane Louise<sup>1</sup> Ceatech <sup>1</sup>Université Paris-Saclay, CEA, List F-91120, Palaiseau, France

In this PhD work, we want to provide a fault mitigation capability at run-time to a Cyber-Physical System (CPS) whose design and implementation are based on a Dataflow Model of Computation and Communication (MoCC).

# Context, Motivations & Objectives

## Deterministic Dataflow MoCC-based CPS design

 Deterministic Dataflow Models of Computation and Communication (MoCC) are well fitted to model and form the base of design and implementations of distributed Cyber-Physical Systems (CPS). The most popular ones are the Synchronous DataFlow (SDF, [1]) and the Cyclo-Static DataFlow (CSDF, [2]). • The Dataflow MoCC PolyGraph ([3]) is one of the most expressive of the deterministic dataflow:

# PolyGraph

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- Below is the PolyGraph modeling of a data fusion system for ADAS.
- Additional frequency and phase constraints on actors (i.e. distributed tasks).
- Rational production and consumption rate instead of integers (for clock domain synchronizations).

## **Runtime Verification**

- Runtime verification tools evaluate the system's behavior at run-time.
- The monitoring of global properties has serious drawbacks.
- The system in [4] re-constructs the global trace from local ones.
- Decentralized monitoring of Linear Temporal Logic (LTL) properties is explored [6].



The actors with a frequency must fire at that frequency. The first fire can be delayed with a phase, like the Display actor. The rates on the channels represent token production/consumption between the actors at both endpoints. The values between brackets are the initials tokens.

Dynamic PolyGraph ([5]) enhances PolyGraph ([3]) with a runtime reconfiguration mechanism.

#### Targeted Contributions

- A Temporal Monitoring Language tailored for a dataflow CPS design.
- A runtime verification tool whose monitoring specifications are derived
- The validation of global properties from local monitoring.
- The rise of an early alert and a reconfiguration process that mitigates

from PolyGraph's static analyses. run-time faults.

# Runtime Adaptation Tool

#### Targeted Tool Overview PolyGraph Static Real-Time Specifications of the Real-Time System Modeling System Analyses Yes Specifications of Monitoring Acceptable Safety & Security procedure behavior ? Properties No Reconfiguration Temporal Monitoring Language

The system provides a fault mitigation capability at run-time. 

#### Use Cases

The Ingenuity Mars Helicopter: Position, velocity, and altitude are estimated using an Inertial Measurement Unit, and navigation adjustments are made using a cam- stereo camera films the road ahead. era.

**An Advanced Driver Assistance** System (ADAS): An odometer measures the current speed, a lidar perceives nearby obstacles, and a





#### Static analyses

- Formalize the Temporal Monitoring Language to specify the actors' (task) execution window, latency, and throughput.
- Define a PolyGraph's mode and the triggering mechanisms.

#### Implementation & Evaluation

- Implement run-time verification & reconfiguration procedures, and quantify the monitor's overhead.
- Evaluation with faults injection and ensure the system detects them.

[1] Lee, E., Messerschmitt, D. (1987). Synchronous data flow. Proceedings of the IEEE, 75(9), 1235–1245. [2] Bilsen, G., Engels, M., Lauwereins, R., Peperstraete, J. (1996). Cyclo-static dataflow. IEEE Transactions on Signal Processing, 44(2), 397–408. [3] Dubrulle, P., Gaston, C., Kosmatov, N., Lapitre, A., Louise, S. (2019). A Data Flow Model with Frequency Arithmetic. Fundamental Approaches to Software Engineering (Vol. 11424, pp. 369–385). [4] Falcone, Y., Nazarpour, H., Bensalem, S., Bozga, M. (2021). Monitoring Distributed Component-Based Systems. International Conference on Formal Aspects of Component Software, 153–173. [5] Dubrulle, P., Gaston, C., Kosmatov, N., Lapitre, A. (2019). Dynamic Reconfigurations in Frequency Constrained Data Flow. Integrated Formal Methods. [6] Bauer, A., Falcone, Y. (2012). Decentralised LTL Monitoring. International Symposium on Formal Methods.

