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Beyond the threaded programming model on real-time operating systems

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18. January 2023 @ NG-RES, HiPEAC
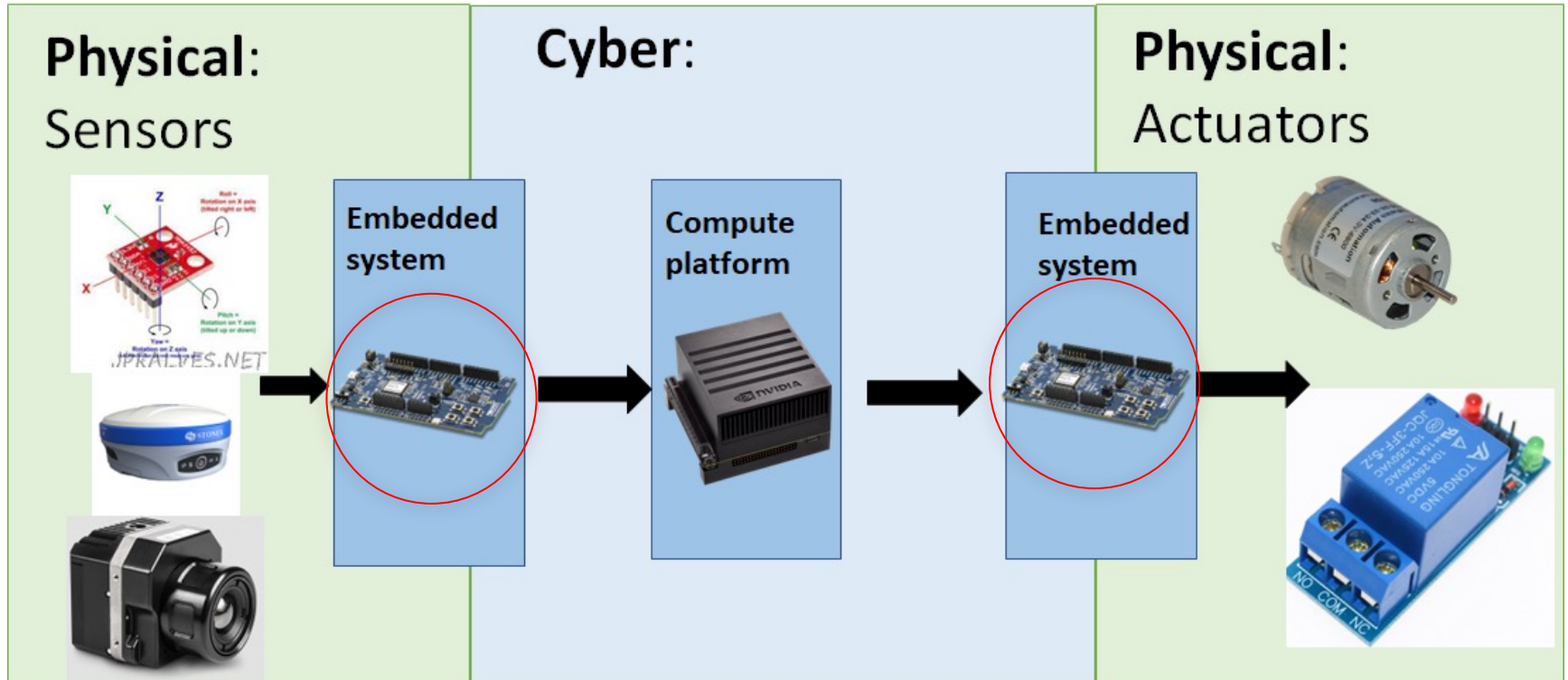Contact: erling.r.jellum@ntnu.no

Who are we?

Where are embedded systems?

Two problems in embedded systems design

1. Concurrency is hard
2. Timing is hard

1. Concurrency is hard

- Embedded systems **are** concurrent

- Shared memory concurrency is a bad idea

- Therac-25 and Toyota unintended acceleration

Therac-25 Medical Accelerator
1985-1987

Radiation therapy device malfunctions, delivers lethal doses at several facilities

The 25 was an improved version of an older model

It could deliver beta-particles (electron beam) or x-rays

By CBSNEWS / AP / May 25, 2010. 7:08 PM

Toyota "Unintended Acceleration" Has Killed 89

A 2005 Toyota Prius, which was in an accident, is seen at a police station in Harrison, New York, Wednesday, March 10, 2010. The driver of the Toyota Prius told police that the car accelerated on its own, then lurched down a driveway, across a road and into a stone wall. (AP Photo/Seth Wenig) / AP PHOTO/SETH WENIG
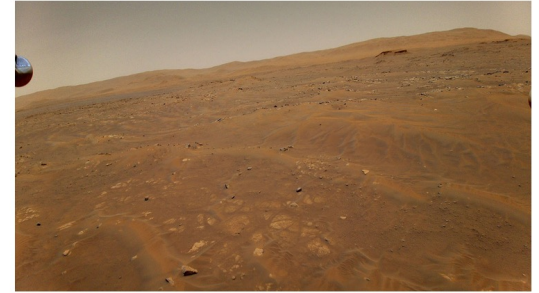
2. Time is hard

1. Accurate timestamping external events

2. Accurately generating external events

3. WCET and schedulability

4. Maintaining a logical timeline

STATUS UPDATES | May 27, 2021

Surviving an In-Flight Anomaly: What Happened on Ingenuity's Sixth Flight

Written by Håvard Grip, Ingenuity Mars Helicopter Chief Pilot at NASA's Jet Propulsion Laboratory

This image of Mars was taken from the height of 33 feet (10 meters) by NASA's Ingenuity Mars helicopter during its sixth flight on May 22, 2021. Credits: NASA/JPL-Caltech. Download image ›

Y2K Repair Bill: $100 Billion
Commerce Estimate Lower Than Others

By Rajiv Chandrasekaran
Washington Post Staff Writer
Thursday, November 18, 1999; Page E01

U.S. businesses and government agencies are being forced to spend about $100 billion to keep the year 2000 glitch from crashing their computers, making a simple two-digit programming "bug" the most expensive peacetime catastrophe in modern history.

Lingua Franca: A solution to all this

In a nutshell

"Lingua Franca is a **polyglot, declarative, coordination language** for concurrent, real-time (and distributed) systems"

```
1   reactor Sensor {
2       output out:int
3       timer t(0,100 msec)
4       state cnt:int(0)
5
6       reaction(t) -> out {= /* Imperative C code here */ =}
7   }
8   reactor Processing {
9       input in:int
10      output out:int
11
12      reaction(in) -> out {= /* Process measurement */ =}
13  }
14  reactor Actuator {
15      input in:int
16
17      reaction(in) {= /* Dr
18  }
19
```


SenseToAct

Sensor
(0, 100 msec)
out in
Processing
out in
Actuator
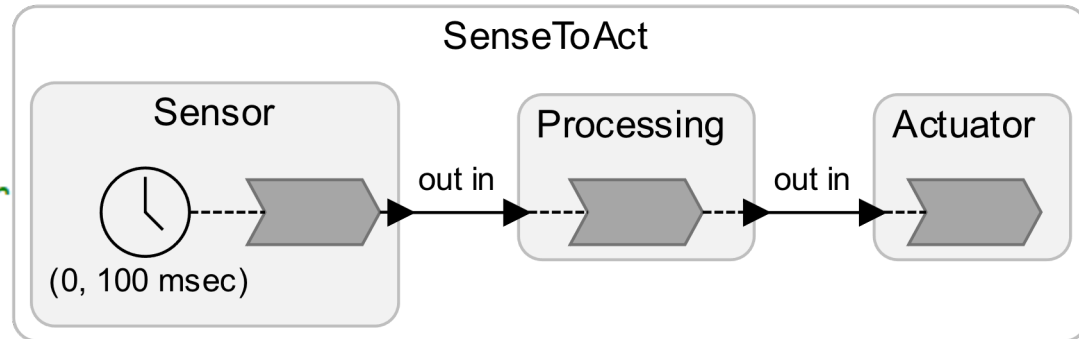
Interaction and real-time

```
1    reactor Interactive {
2        physical action a;
3        reaction(a) {= =}
4    }
```

```
1    reactor Deadline {
2        input in:int
3        reaction(in) {= =} deadline (50 msec) {=
4            // Deadline miss handler here
5        =}
6    }
```
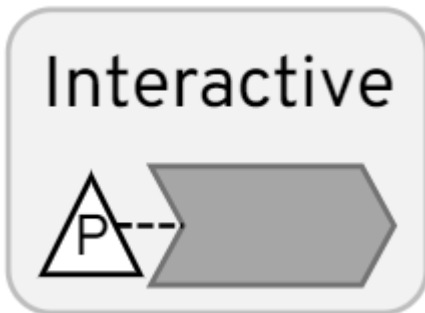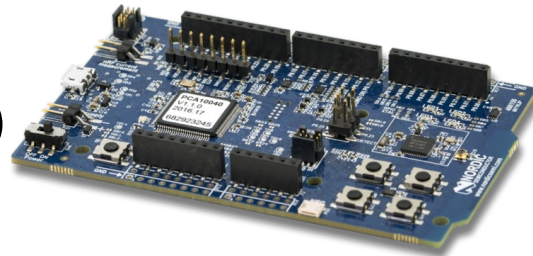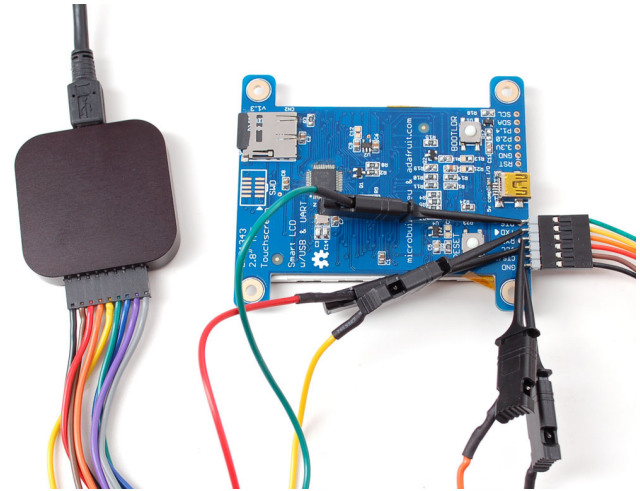
Lingua Franca on embedded systems

Reactor 1	Reactor 2	Reactor 3	Reactor 4		Zephyr task 1	Zephyr task 2
LF C-runtime						
LF Zephyr support						
Zephyr Counter API		Zephyr kernel API				
Zephyr OS						
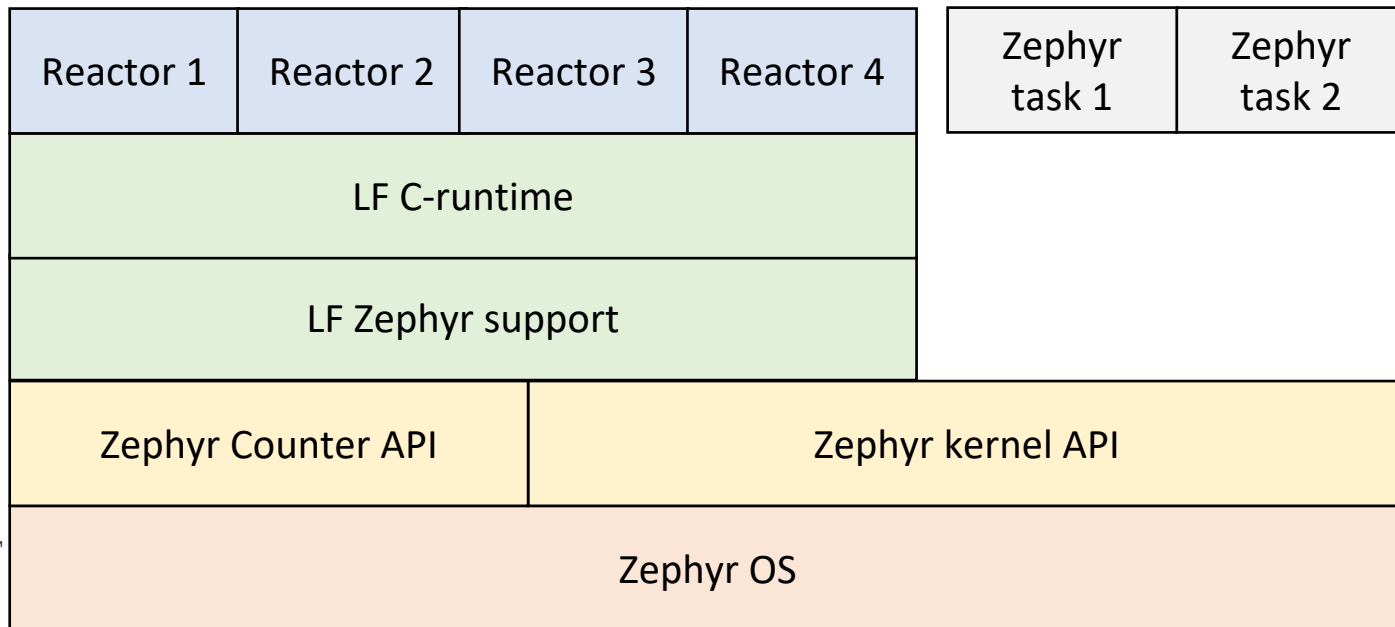
How to evaluate embedded systems frameworks

1. Average-case performance (**Savina+ThreadMetric**)
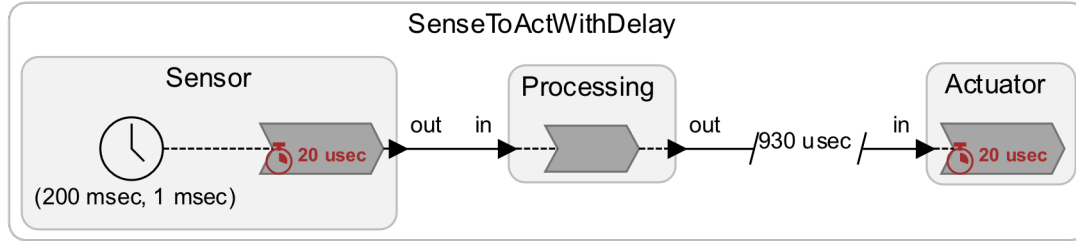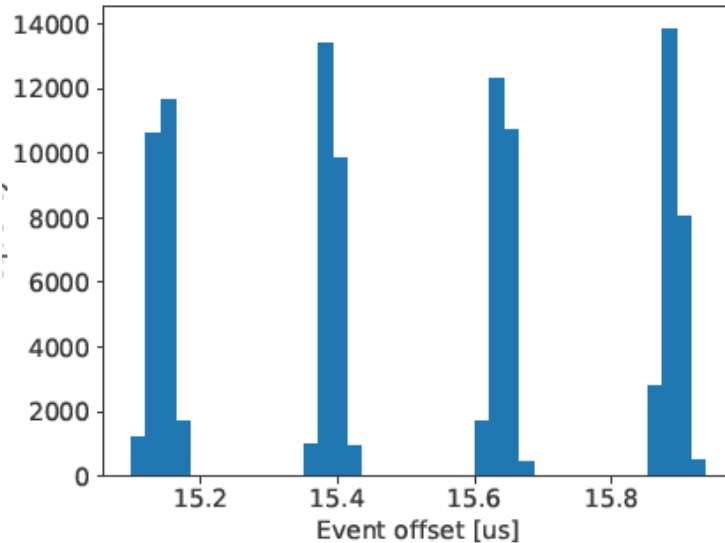2. Time precision benchmarks (**PWM generator**)
3. Interrupt latency

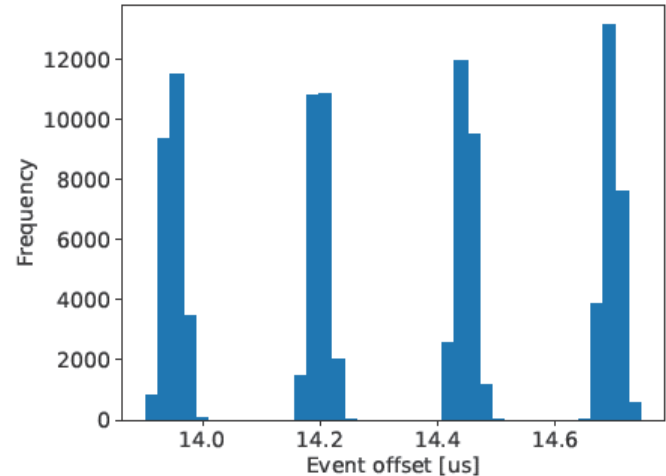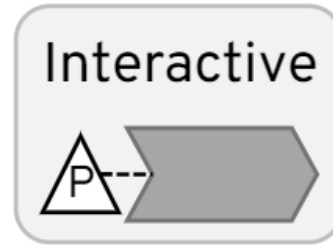Platform: nRF52 (64MHz)

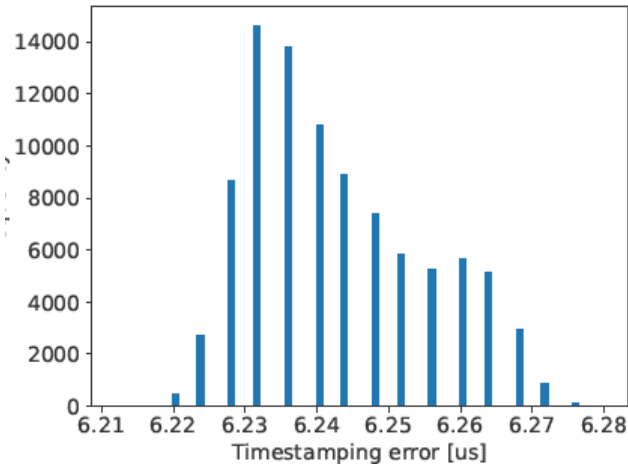# Average-case performance
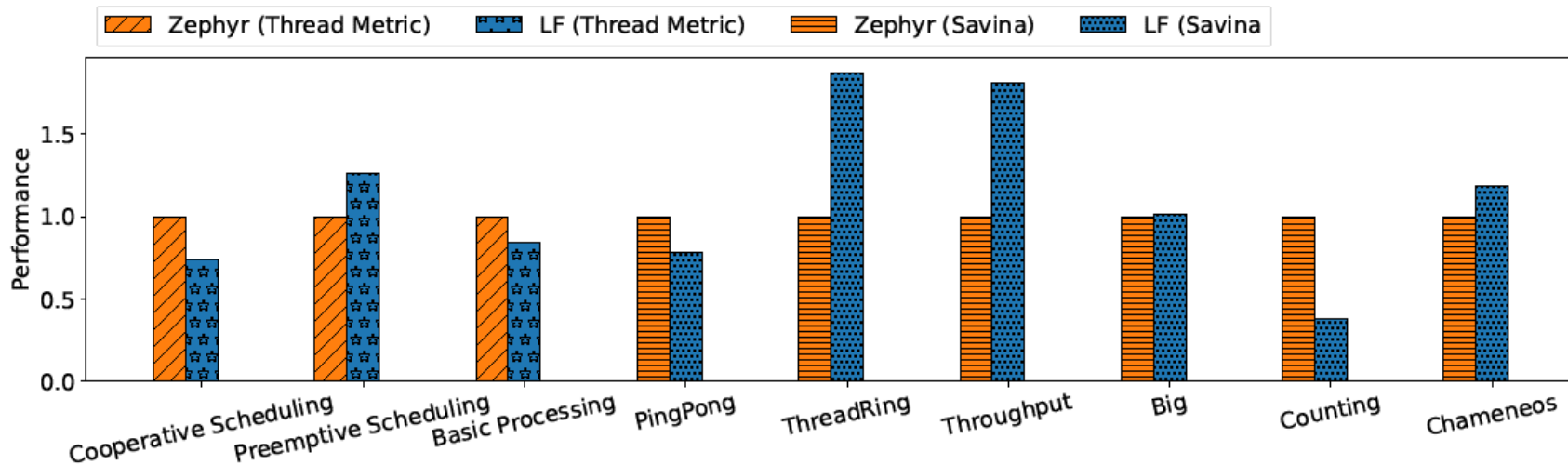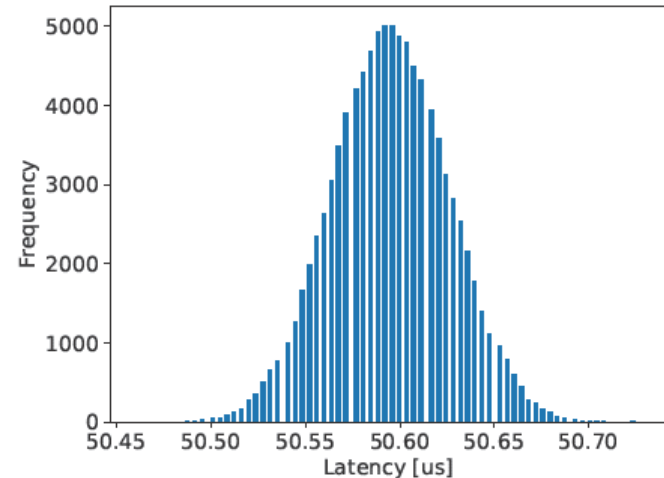
Precision at Sensor and Actuator

Interrupt timestamping precision and latency

Interactive

Physical action timestamping precision

Physical action latency

Thank you

- Web page: https://www.lf-lang.org/
- Github: https://github.com/lf-lang/lingua-franca