Using CPAL to model and validate the timing behaviour of embedded systems

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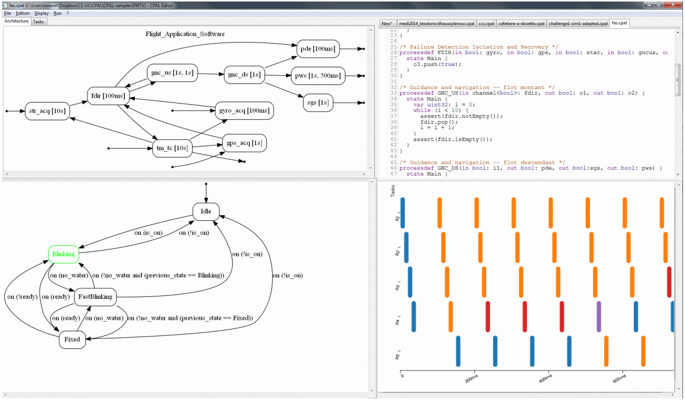
RTaW RealTime-at-Work

FMTV Challenge - WATERS 2015 - Lund

Cyber Physical Action Language (CPAL)

- C-like **intuitive language** (with automata and real-time abstractions)
- model **functional** and **temporal** behaviour of CPS
- **simulate** CPS (both types of behaviour)



(still under development)

The **challenging part** of the challenge

- **not** a **standard** scheduling problem
- hidden **ambiguity** in the model
- pen & paper solutions seemed trivial

How to **solve** the challenge with **CPAL**

- **low effort** to model the challenge
- **quick simulation** results
- explicit dis-ambiguity

(yet, simulation $\neq$ formal verification)

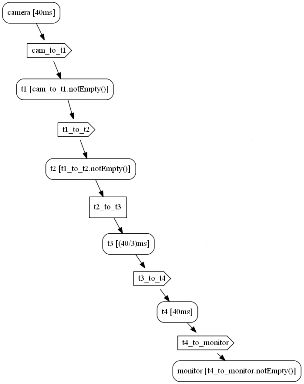
CPAL Model of Challenge 1

```
struct Frame {
  uint32: id;
  uint32: emission_time;
};

processdef T1_PreProcessor(
  in channel<Frame>: input,
  out channel<Frame>: output)
{
  state Main {
    /* removes reflections
       normalizes intensity, etc. */
    assert(input.notEmpty());
    output.push(input.pop());
  }
}

var queue<Frame>: cam_to_t1[1];
var queue<Frame>: t1_to_t2[1];
var Frame: t2_to_t3;
var queue<Frame>: t3_to_t4[n];
var queue<Frame>: t4_to_monitor[1];

process T1_PreProcessor:
  t1[cam_to_t1.notEmpty()](cam_to_t1, t1_to_t2);
  @cpal:time {
     t1.execution_time = 28ms;
  }
  ...
```

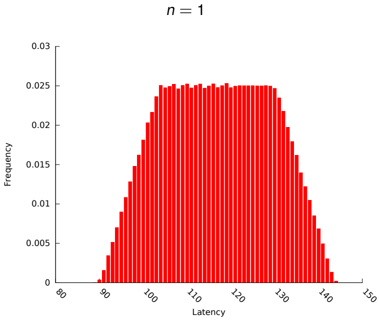


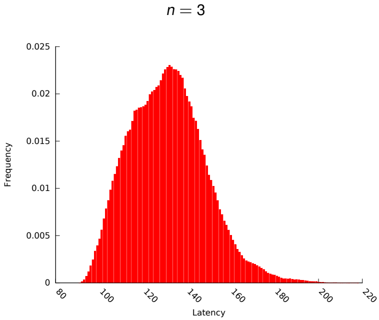
Explicit Disambiguation

- task release times
- mutable or immutable clock drifts
- clock drift distribution
- execution time distribution

always the least-favorable configuration chosen

Simulation of Challenge 1A





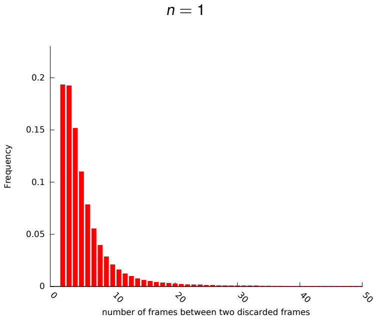
- 10^8 frames in total simulated (in less than 8 hours)
- 10^3 release patterns, 10^5 frames per pattern
- mutable drifts
- normal distributions

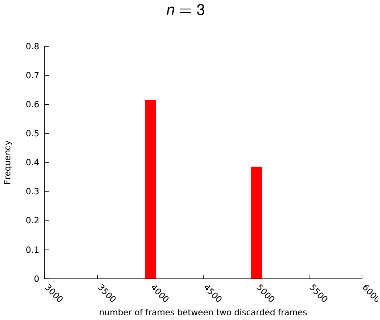
Simulation vs. Pen & Paper

	buffer (n)	frame	simulation	pen & paper
min	1	1	63 ms	63 ms
	1	> 1	89.7694 ms	89.6656 ms
	3	1	63 ms	63 ms
	3	> 1	90.0226 ms	89.6656 ms
max	1	-	144.9224 ms	$<$ 146 ms
	3	-	222.9026 ms	$<$ 226 ms

Error in first pen & paper solution identified using simulation

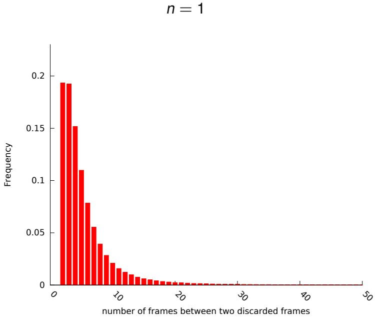
Simulation of Challenge 1B

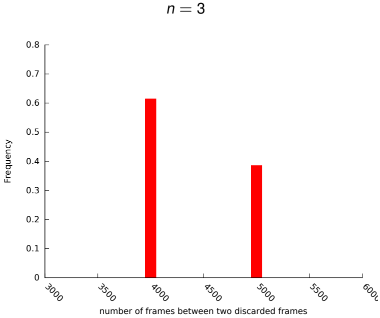




- 10^8 frames in total simulated (in less than 8 hours)
- 10^3 release patterns, 10^5 frames per pattern
- immutable drifts, worst-case clock drifts
- normal distribution of exec time

Simulation of Challenge 1B: Observations



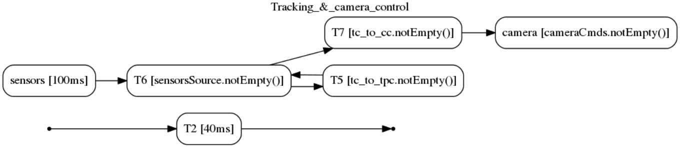


- minimal distance: 2
- overload situations
- lost frames very frequent

- minimal distance > 3800
- no bursts
- two spikes

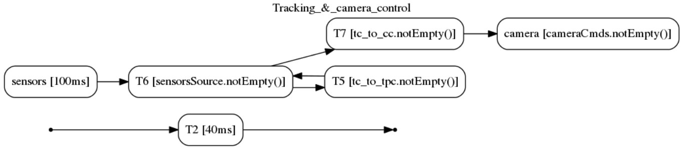
No pen & paper solution to 1B.

CPAL Model of Challenge 2



Simulation of Challenge 2

- CPAL simulation does not yet support pre-emption



- taskset *T*5, *T*6, *T*7 mutually non-pre-emptive (simulation possible)
- taskset *T*5, *T*6, *T*7 treated as artificial task *Tx*:
- $\Rightarrow$ reduction to standard response-time analysis!

Conclusions

CPAL doesn't offer **automated** formal verification, but:

- **intuitive modelling** (< 4 hours for the both challenges)
- **quick simulation** (< 8 hours for all simulations)
- **unambiguous description**

Integration with formal verification tool future work.