Towards a declarative modeling and execution framework for real-time systems

Sebastian Altmeyer, Nicolas Navet

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More than 35 years of Research in Real-Time Systems

with some very impressive results and applications ...
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... but timing is still a mere side-product.
Design of an real-time/cyber-physical system:

- timing behaviour happens
  (side product of the functional behaviour)
- timing verification after system integration
- system designer must be aware of all scheduling details
  few abstractions provided
- even dedicated design tools avoid timing specification
  (Matlab, SCADE/Esteral, Ascet)
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⇒

timing is not treated as a first-class citizen
Principles of our declarative framework:

1. Designer only declares the desired timing behaviour.
2. Show only what is needed to the designer, hide the rest.
3. Simplicity is key.

Premise: Better abstraction of a system’s timing behaviour needed!
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Example: Specifying timing behaviour

State-of-the art: Plenty of design choices and details.

- Do we allow pre-emption?
- Static or dynamic scheduling?
- Which scheduling policy?
- Dynamic or static priorities?
- How to assign priorities?

Concentrates on how to realize the timing behaviour
Example: Specifying timing behaviour

Our vision: **Only declare timing correctness.**

<table>
<thead>
<tr>
<th>4 simple types of constraints*:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Execution frequency:</strong> process $\tau_a$ executes every $[x : y]$ seconds.</td>
</tr>
<tr>
<td><strong>Conditional execution:</strong> process $\tau_a$ executes (i) if its period has elapsed and (ii) if condition C evaluates to true.</td>
</tr>
<tr>
<td><strong>Relative deadlines:</strong> process $\tau_a$ must complete within $y$ seconds.</td>
</tr>
<tr>
<td><strong>Temporal dependencies:</strong> process $\tau_a$ must execute after process $\tau_b$ has finished.</td>
</tr>
</tbody>
</table>

*(Complete? Probably not, but sufficient to start with.)*

Concentrates on **what instead of how**, environment does the rest.
Designer writes the functional and timing model
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Designer Perspective

- Designer writes the functional and timing model
  ... in the way it shall behave on the system.
- Hide as many details as possible
Designer writes the functional and timing model
... in the way it shall behave on the system.

Hide as many details as possible
... but show how it will behave.
The complete picture

- Functional Model
- Timing Model
- Simulator

Hidden details

- Runtime Environment

User View
The complete picture
The complete picture
Runtime Environment

- uniprocessor system
- a system-wide clock
- time-triggered task release + FIFO queues
- prototype environment for Raspberry Pi
FIFO Scheduling: Why?

▶ easy to implement
▶ non-pre-emptive policy
▶ unique event-order
▶ ensures equivalence between
  (i) runtime behaviour
  (ii) simulation
▶ (work-conserving)
▶ resilient to overload conditions
▶ but not as performant as EDF/RM
FIFO Scheduling: How?

- \( n \) processes (tasks) \( \{\tau_1, \ldots \tau_n\} \)
- for each process \( \tau_i \): \( (O_i, C_i, T_i, D_i) \),
  - \( O_i \): offset
  - \( C_i \): execution time bound
  - \( T_i \): period (strictly periodic)
  - \( D_i \): relative deadline
Scheduler Synthesis

(i) Period Selection: Try:
   1. Best Performance
   2. Minimal Hyperperiod
   3. Lowest Utilization

(ii) Offset Optimization:
   distribute the workload and avoid load peaks
The complete picture
The complete picture

- Functional Model
- Timing Model
- Simulator
- User View
- System View
- Timing Analysis
- Timing Bounds
- Scheduler tbd
- Scheduling Configuration
- Runtime Environment

Design Time

Runtime
The complete picture, partly integrated

Design environment (Cyber-Physical Action Language CPAL)\(^1\)

\(^1\)https://www.designcps.com/
The complete picture, partly integrated

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1. https://www.designcps.com/
The complete picture, partly integrated

Design environment (Cyber-Physical Action Language CPAL)¹

1 https://www.designcps.com/
Conclusions

Is it possible to just declare what **what** correct timing behaviour means, instead of defining **how** it is realized?

Declarative modeling and execution framework

- hide as much as possible from the designer
- automatize what’s possible
- simplicity and usability in mind
Questions?