Mixed-Criticality Job Models: A Comparison

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University of North Carolina at Chapel Hill
Mixed-Criticality Systems

• **MC Systems:** *functionalities of different levels of importance (criticalities)* are implemented upon a *shared platform.*
Mixed-Criticality Systems

- **MC Systems**: functionalities of different *levels of importance* (*criticalities*) are implemented upon *a shared platform*.

- Traditional non-MC design: 
  Need significant *resource over-provisioning* to guarantee their *temporal correctness*, which leads to highly *inefficient resource usage* at run-time!
Mixed-Criticality Systems

- **MC Systems**: functionalities of different levels of importance (*criticalities*) are implemented upon a shared platform.

- Traditional non-MC design:
  Need significant resource over-provisioning to guarantee their temporal correctness, which leads to highly inefficient resource usage at run-time!

- **MC**:
  Over-provisioned resources (to more important tasks) can be used to execute less important ones.
Models

Temporal Correctness

Real-Time Cyber-Physical SYSTEMS

SAFETY-CRITICAL
Models

Temporal Correctness

Analyzing

MODELS

Modeling

Real-Time Cyber-Physical SYSTEMS
Models

Real-Time Cyber-Physical Systems

Too Complicated

Modeling Schedulability Lost

Modeling

More or Less Simple

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Model Complexity

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Models

- Temporal Correctness
- Analyzing
- Modeling
- Real-Time Cyber-Physical Systems

Release Time & Deadline
Single WCET: C

L.L.
Models

Temporal Correctness

Analyze

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Real-Time Cyber-Physical SYSTEMS

L.L. MODEL

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Example: \( x := a + b \)

3~9~321 cycles
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"Exact" MODEL

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Real-Time Cyber-Physical SYSTEMS

Analyzing
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Release Time & Deadline
Criticality Level (A,B,C,D)
WCETs: C(A), C(B), C(C), C(D)

Schedulability Lost

Vestal

“Exact”

Model Complexity

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Vestal MODEL

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Model Complexity

Designer’s Preference

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Models

Release Time & Deadline
Criticality Level (A,B,C,D)

Two WCETs: C(self), C(normal)

Schedulability Lost

L.L. Burns Vestal "Exact"

Model Complexity

Burns MODEL

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Example: $x := a + b$

3~9~321 cycles
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**Level of the System** :=

- Smallest $\ell$ that $C_i(\ell)$ caps behavior of job $i$, $\forall i$
- $\chi_i$ of the greatest-criticality job exceeding its $C_i(\text{NL})$

**Example:** $x := a + b$

3~9~321 cycles

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**Proposition 1:**
Any instance represented in the Burns model can be represented exactly in the Vestal model.

- Example: $x := a + b$
  - 3$\sim$9$\sim$321 cycles

- Actual **execution time** remains **unknown** until the job *signals* its completion.
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**Proposition 2:**
Instances represented in the Vestal model cannot always be represented exactly in the Burns model.

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3~9~321 cycles

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(Non-clairvoyant)
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Schedulability Lost

- L.L.
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Model Complexity

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**Proposition 3:**
Determining whether a given instance specified according to the Burns model is MC-schedulable is NP-hard in s.s.
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**Thm 1:**
There are MC instances with $L$ distinct criticality levels specified using the Burns model that are clairvoyantly-schedulable, but that are not schedulable for any fixed priority policy on a processor that is less than $s_L^*$ times as fast.

$s_L^*$ is the root of $x^L = (1 + x)^{L-1}$, i.e., the speedup bound under Vestal model.
Conclusion

• We seek to better understand the Ease-of-use Burns model.

• Unfortunately, we have not identified any analytical benefits in terms of reduced complexity of feasibility analysis, less schedulability loss, etc., at the cost of reduced expressiveness.
Conclusion & Future Work

• We seek to better understand the Ease-of-use Burns model.

• Unfortunately, we have not identified any analytical benefits in terms of reduced complexity of feasibility analysis, less schedulability loss, etc., at the cost of reduced expressiveness.

• Limitation: Fixed-Priority; Job Set; Uniprocessor.
Thank you!

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