Multi-Model Systems – an MCS by any other name

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Why is MCS such a popular topic?

- The review on MCS, by Rob and I (available from my home web site) currently covers up to end of Feb 2020, is 87 pages long and has 550+ citations
- In 2020 I estimate over 30 further refereed papers have been published
- This is the 8th workshop on MCS at RTSS - and there have been many other such events
- But the notion of criticality in Vestal's paper is quite specific
- And has been criticised as being of little practical value
- So why is MCS research so popular?

Multi-Model Systems

- The distinctive feature of the task model introduced by Vestal is that the key defining parameters of each task: period, T, deadline, D and worst-case execution time, C are not single valued
- For example, it is possible for a task to have more than one C value
- In general, a task (set) may have more than one model that defines its behaviour
- Criticality is just one criteria to exploit this multi-model approach
- There are many others

Multi-Model Systems

- What Vestal proposed is that different stakeholders would want to assign different values to some of the task parameters (C is his work)
- In effect there is not one but a collection of models that are being applied to the taskset
- Hence the name proposed here for the abstraction of a system of tasks having more than one model
- The rich body of results that have appeared under the umbrella of MCS do not require or assign any particular meaning to the term ‘criticality’; what they utilise and exploit is the idea that there is more than one interpretation of the temporal properties (i.e. parameters) of the tasks under consideration

Multi-Model Systems

- An MMS has the usual task parameters, but in addition there are one or more meta-parameters that are additionally assigned to each tasks
- Example meta-parameters are *criticality*, *importance*, *value*, *robustness*, *resilience*, *security level* and many forms of functional modes of operation
- Typically they take one of a small number of discrete values
- The usual temporal parameters, T, D, C, blocking B, offset O and, for example, DAG parameters total work W and span S are defined over the ranges of these meta-parameters

Application of MMS(1)

- Hard Real-Time Systems
  - Criticality is a meta-parameter (*LO* or *HI*)
  - WCET estimates $C(HI)$ and $C(LO)$ are both expected to be safe, but $C(L)$ is less assured
  - Research here focuses on Verification
- Soft Real-Time Systems
  - Importance is a meta-parameter (*LO* or *HI*)
  - WCET estimate $C(HI)$ is assumed safe; $C(LO)$ is likely to be (rarely) exceeded
  - D and T may be parameterised by importance
  - Research here focuses on Survivability (Robustness and Resilience)
- Systems can have both meta-parameters: Criticality and Importance

Application of MMS(2)

- Fault Tolerance and Graceful Degradation
  - Criticality and Importance are meta-parameters
  - C and C^+ - where C^+ incorporate the fault accommodation code (FAC)
  - Fault model (survive m faults every t time units) may be a function of criticality
  - D and T may be parameterised by importance
  - Research here focuses on Survivability of hardware/software faults

Application of MMS(3)

- Value-Added Computation
  - Value is a meta-parameter
  - C and C^+ - where C^+ incorporates the value added code
  - D and T may be parameterised by value
  - Research here focuses on QoS
- Importance and Value:
  - Importance – what to do when system is overloaded
  - Value – what to do when system is under-loaded

Application of MMS(4)

- Adaptability
  - Performance is a meta-parameter (opt – optimised typical behaviour or ens – ensured worst-case behaviour)
  - All system parameters have a worst-case and a typical estimate
  - Worst-case can be either maximum or minimum
  - Ensure system is correct (safe) if worst-case (ens) estimates used, but
  - Optimise (opt) if typical estimates are used and encountered
- This approach has been shown to be useful in controlling network traffic (maximum and typical delays), preemption points (maximum and typical durations) and Learning-Enabled Computation, LEC (minimum and typical value, or confidence)

Multi-Model not Multi-Modal

- A system that sequentially moves between different functional modes is termed multi-modal
- There are many similarities with multi-model and multi-modal
- Many forms of analysis for MCS involve modes of behaviour, and mode-change protocols
- But MMS incorporates the simultaneous/concurrent application of differing view as to the defining parameters of the systems

Towards a New System Model

- System defined by primary parameters and meta-parameters
- A system may have more than one meta-parameter
- Meta-parameters may take no role in the run-time scheduling of the system. Or they can act as primary parameters as well as meta-parameters

Towards a New System Model

- A meta-parameter is defined to be *ordered* if it affects a primary parameter (P) in a consistent way; so if $m1$ and $m2$ are two arbitrary values of the meta-parameter M, and if for some task τ_i: $P_i(m1) \geq P_i(m2)$ then for all other tasks τ_j: $P_j(m1) \geq P_j(m2)$
- If all primary parameters are ordered then the meta-parameter is said to be *monotonic* a
- To complete, we note that there are also a class of derived parameters. Examples here are priority and virtual deadline

Conclusion

- I have argued that there should be a separation between the analytical results that have been developed following Vestal's publication and the application of these results to the rather narrow area of mixed-criticality systems
- The results developed for MCS are more generally applicable
- I argue for a recognition of this situation by defining the properties of systems for which the developed research applies
- This leads to the term Multi-Model being used to focus on the essential property: that key task/job/agent/message parameters are open to more than one interpretation

- All that remains is to rename the workshop!!