Time/Event Triggering is Orthogonal to State/Event Observation

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“Periodic time-triggered state observations or sporadic event-triggered event observations are two alternative approaches for the observation of a dynamic environment in order to reconstruct the states and events of the environment at the observer. Periodic state observations produce a sequence of equidistant “snapshots” of the environment that can be used by the observer to reconstruct those events that occur within a minimum temporal distance that is longer than the duration of the sampling period. Starting from an initial state, a complete sequence of (sporadic) event observations can be used by the observer to reconstruct the complete sequence of states of the RT entity that occurred in the environment. However, if there is no minimum duration between events assumed, the observer and the communication system must be infinitely fast.”
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Claim:

- state observation → time triggered → periodic
- event observation → sporadic
State vs Event Observations (DSoS)
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• State observation (in “state message” (SM))
  - records the value of a state variable at a given time
    < Name (of state variable) ; Value ; $t_{obs}$ >

  😊 idempotency (can be processed many times)
  😊 loss tolerance (new observations supercede old ones)
State vs Event Observations (DSoS)

- **State observation (in “state message” (SM))**
  - records the value of a state variable at a given time
    
    \(<\text{Name (of state variable)}; \text{Value}; t_{\text{obs}}>\)

  - 
    - \(\text{idempotency (can be processed many times)}\)
    - \(\text{loss tolerance (new observations supercede old ones)}\)

- **Event observation (in “event message” (EM))**
  - records the occurrence of an event
    
    \(<\text{Name (of event)}; \{\text{Attributes}\}; t_{\text{event}}>\)

  - \(\text{event messages contain potentially less data than state messages}\)

  - \(\text{may be indispensable if:}\)

    “state variable” cannot feasibly be observed, or
    
    need general “events” such as “transfer \(X \in \) from \(A\) to \(B\)”
Event vs Time Triggering
Event vs Time Triggering

- Event triggering (ET)
  - occurrence of event triggers communication, processing, sampling...
  - only trigger when “significant happenings” occur
Event vs Time Triggering

- **Event triggering (ET)**
  - occurrence of event triggers communication, processing, sampling...
  - only trigger when “significant happenings” occur

- **Time triggering (TT)**
  - occurrence of clock tick triggers communication, processing, sampling...
  - and
    
    common knowledge about “clock ticks”
    (e.g., synchronized clocks or bounded local clock drift)

- common knowledge about maximum periods allows “communication by time” (cf. heartbeats)
Periodic Sampling
Periodic Sampling

- Sample every $T (TT + SM)$
Periodic Sampling

- Sample every $T (TT + SM)$
- Signal change every $T (TT + EM)$
"\[\text{-Sampling}\]
"D-Sampling"

- Signal every change of amplitude = \( d (ET + EM) \)
“□-Sampling”

• Signal every change of amplitude = □ (ET + EM)
• Sample if change of amplitude = □ (ET + SM)
"Δ-Sampling"

- Signal every change of amplitude = \( \Delta (ET + EM) \)
- Sample if change of amplitude = \( \Delta (ET + SM) \)
• Signal every change of amplitude $= \square (ET + EM)$
• Sample if change of amplitude $= \square (ET + SM)$
“Sporadic []-Sampling”

• Signal every change of \( \Box \); at most once per \( T \) \((ET/TT + EM)\)
• Sample if change of \( \Box \); at most once per \( T \) \((ET/TT + SM)\)
“Sporadic []-Sampling”

- Signal every change of [] at most once per $T (ET/TT + EM)$
- Sample if change of [] at most once per $T (ET/TT + SM)$
“Periodic []-Sampling”

- Signal every change of $\Delta$; signal change every $T$) $(TT/ET + EM)$
- Sample if change of $\Delta$; sample at least once every $T$) $(TT/ET + SM)$
"Periodic □-Sampling"

- Signal every change of □; signal change every T \( (TT/ET + EM) \)
- Sample if change of □; sample at least once every T \( (TT/ET + SM) \)
Variable Period $\square$-Sampling

- Sample (or signal change) if change $\geq d$
- subject to inter-sample time $\in [T_{min}; T_{max}] (ET/TT + SM(EM))$
“Variable Period \( d \)-Sampling”

- Sample (or signal change) if change \( \geq d \)
- subject to inter-sample time \( [T_{min} ; T_{max}] \)

\[ \text{decreases bandwidth use} \]

\[ d \]

\[ \text{(ET/TT + SM(EM))} \]
"Variable Period Sampling"

- Sample (or signal change) if change $\geq d$
  subject to inter-sample time $\in [T_{min}; T_{max}]$ $(ET/TT + SM(EM))$

- decreases bandwidth use

limits maximum arrival rate
“Variable Period φ-Sampling”

- Sample (or signal change) if change ≥ φ
  subject to inter-sample time [Tmin ; Tmax] \((ET/TT + SM(EM))\)

- limits maximum arrival rate
- decreases bandwidth use
- allows communication by time
• etc.

**see abundant literature on**

- signal processing
- information theory

...
Conclusion
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• So, integration of ET/TT and EM/SM paradigms is indeed worthwhile!
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  “ET+EM” vs “TT+SM”

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• But:
  - state message semantics
  - common knowledge about time
  - common knowledge about periodic events
Conclusion

• Real-time system design should not be reduced to a (false) dichotomy: “ET+EM” vs “TT+SM”

• So, integration of ET/TT and EM/SM paradigms is indeed worthwhile!

• But:
  - state message semantics
  - common knowledge about time
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are surely useful (indispensable?) in critical systems (esp. fail-safe systems)
Getting back to basics — another contribution!

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<thead>
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<th>Event messages</th>
<th>State messages</th>
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<tr>
<td>Aperiodic (arbitrary $\Delta T$)</td>
<td>&quot;Sporadic $\Delta$-Sampling&quot;</td>
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<tr>
<td>Minimum $\Delta T$</td>
<td>&quot;Periodic $\Delta$-Sampling&quot;</td>
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<td>Minimum et maximum $\Delta T$</td>
<td>&quot;Variable Period $\Delta$-Sampling&quot;</td>
<td>&quot;Periodic Sampling&quot;</td>
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<td>Periodic (fixed $\Delta T$)</td>
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- **Event-triggering**
- **Time-triggering**