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A behavior model for IEC 61499 function blocks

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Plan

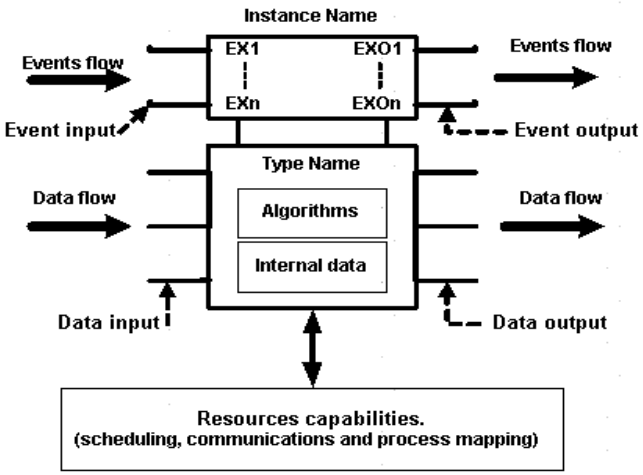
- Context
- IEC 61499 standard concepts
- Problematic
  - Model of FB behavior
  - Temporal interoperability property
- Contributions
  - Addition of some semantics to the standard
  - Proposition of modeling approach
  - Proposition of an offline scheduling approach
- Conclusion and future works

Context

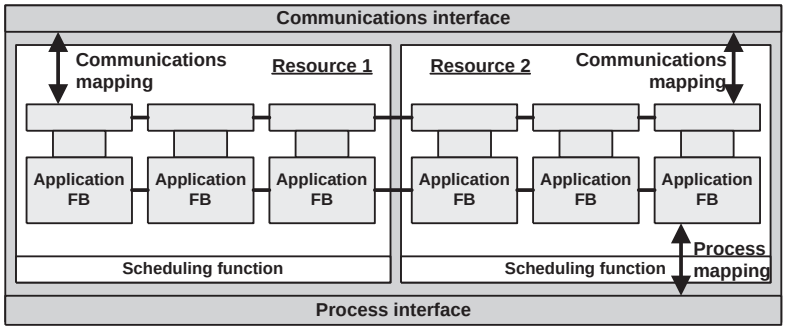
- Validation and design of Embedded Real Time Systems
  - Functional properties
  - Extra-functional properties
- Component based approaches
  - Composition at Run Time
  - Composition at Off-line (at design time)
- Function Blocks
  - IEC 61131.3
  - IEC 61499

The IEC 61499 concepts

- **Function Block**
  - **Interface**
    - Data inputs / Outputs
    - Event inputs / Outputs
  - **Implementation**
    - Head
      - The Execution Control Chart (ECC)
    - Body
      - Algorithms: the FB functionalities
      - Internal data



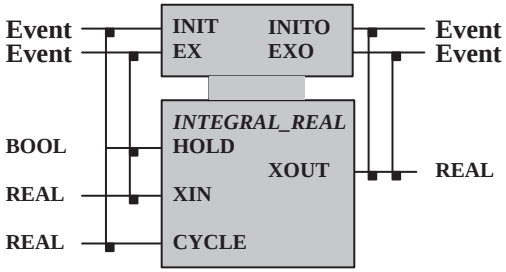
- **Device**
  - **Processing unit(s), sensor(s), actuator(s), network interface(s)**
  - **Resource(s): logic execution unit(s)**

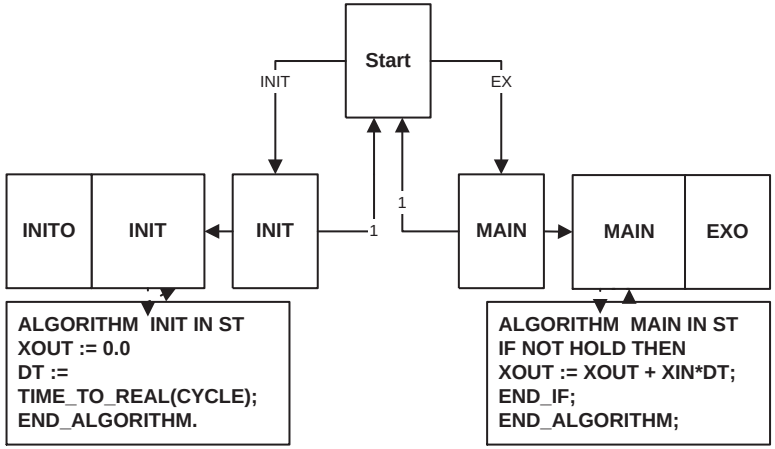


- **Control application = FBs network distributed on**
  - **One or several resources**

The ECC behavior

- **Selects** one of the simultaneous occurrences.
  - ⇒All the others occurrences are lost
- **Activates** the algorithms sequence
- **Waits** for the resource scheduler
- **Emits** the corresponding output event(s) at the execution end





Problematic

- **The selection mechanism is not clear in the standard**
  - **What is the meaning of simultaneous occurrences???**
  - **How can we perform the selection policy???**

- **The loosing phenomena is a very critical problem**
  - **How can we characterize such problem???**
  - **How can we avoid such problem??**

Enrich the standard IEC 61499

- Input events characterizations
- Proposition of a FB behavior model
  - Priority rules
  - Not ambiguous
  - Optimal
- Proposition of an offline scheduling strategy
  - Temporal interoperability constraints
  - Optimal Scheduler model
    - Idling / Non-Idling
    - Deterministic
  - Regular events flow inside a Control Application

Problem 1

The selection mechanism is not clear in the standard

Contribution

A FB behavior model

The proposed FB behavior model

- A FBj characterization
  - n event inputs : $EX_1, \ldots, EX_n$
  - m event outputs : $EXO_1, \ldots, EXO_m$. $m \leq n$
  - n algorithms : $Alg_{(j,1)}, \ldots, Alg_{(j,n)}$
    - **$BCET(Alg_{(j,i)})$: Best Case Execution Time**
    - **$WCET(Alg_{(j,i)})$: Worst Case Execution Time**
- Modeling approach
  - Timed Automata formalism
- Simultaneous occurrences EXi, Exj

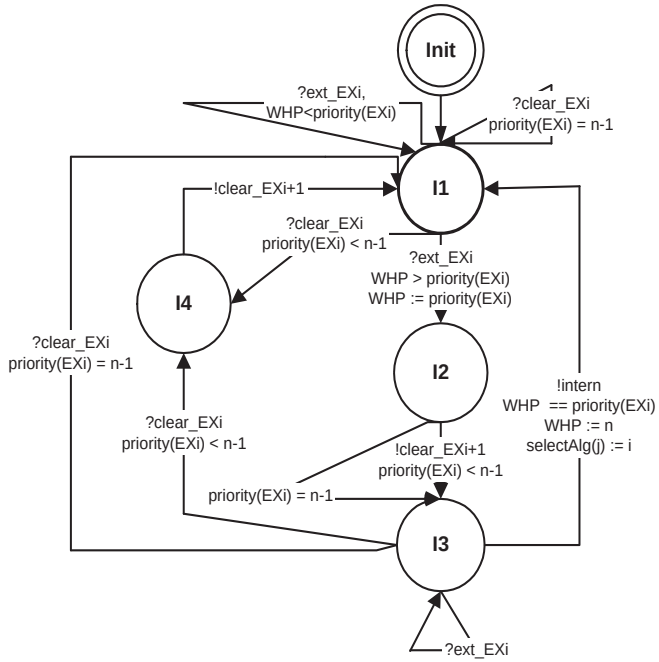
  $\Rightarrow$ t(EXi), t(EXj) between two selection operations
- Event inputs selection mechanism
  - <u>A unique priority</u> for each event input
  - The event input <u>selection policy</u>
    - memorization of the highest priority event occurred from the last selection

The event input model

Selection mechanism

- *priority(EXi)*: the priority level of the event input EXi
- *WHP* (Waiting Highest Priority)
  - Variable storing the highest priority of events occurred from the last selection
  - Initialized to n (the event inputs number)
- An event occurs on EXi
  - **<u>If</u>** WHP ≤ priority(EXi)

    <u>Then</u> the occurrence is <u>lost</u>
  - **<u>Else</u>**
    - **WHP := priority(EXi)**
    - **All the other input occurrences are discarded**
    - **The state machine waits the ECC**

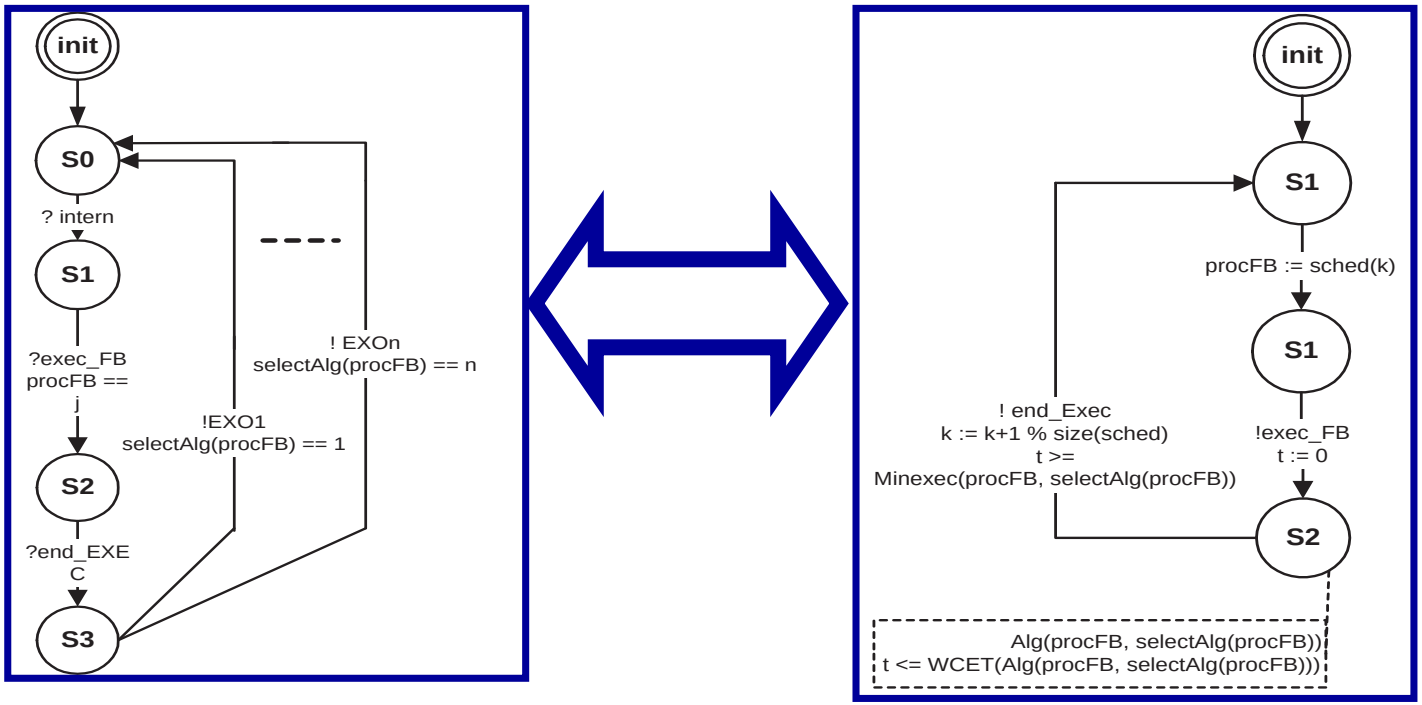


The ECC model

- Selection of an input occurrence
- Interaction with the Sheduler
- Emission of the corresponding output occurrences

The resource model

- Periodic Offline scheduling stored in the array sched



Problem 2

The loosing phenomena is a very critical problem

Contribution

temporal interoperability properties

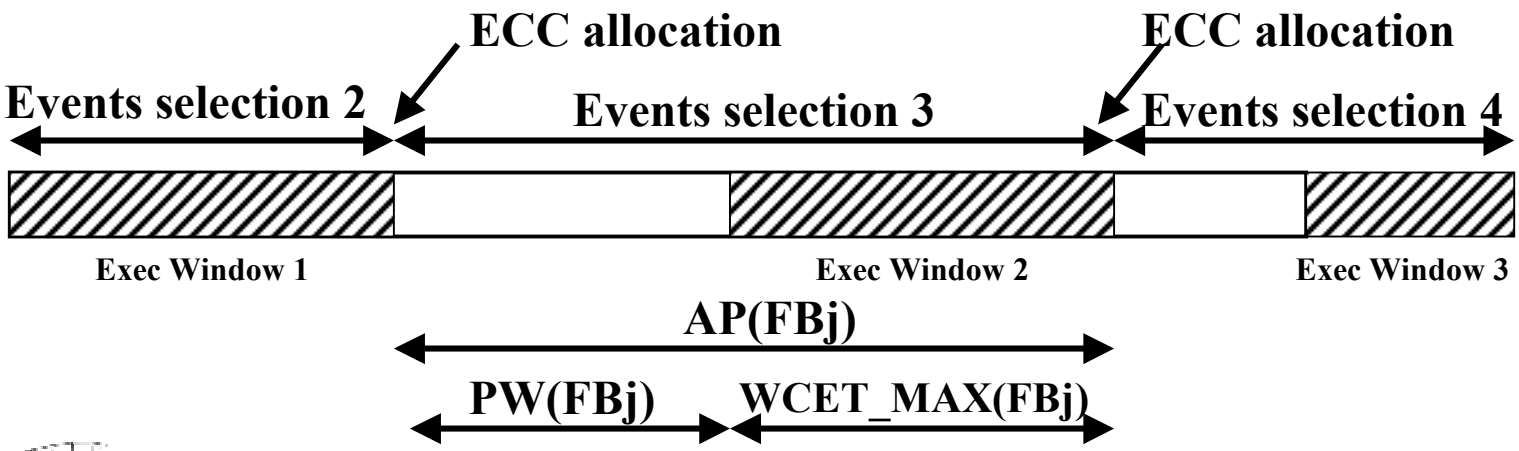
Input events characterizations

- FBj input events characterization
  - $EX_1, EX_2, \ldots, EX_n$
  - Periodic event EXi: $Of(EX_i)$, $P(EX_i)$, $G(EX_i)$
- **Definition:** The longest worst case execution time in FB_j

$$WCET\_MAX(FB_j) = Max_{\ i \in [1,n]}\{WCET(Alg_{(j,i)})\}$$

- **Definition:** PW(FBj): the scheduler worst waiting time in ECCj
- **Definition:** The worst ECCj activation period

$$AP(FB_j) = PW(FB_j) + WCET\_MAX(FB_j)$$



Temporal interoperability property (1)

- <u>The schedulability condition 1</u>

  The scheduling policy avoids loosing occurrences for the function block FB if it respects the condition

  $$\forall i = 1..n,\ \forall j = 1..n,\ \forall k, m \text{ integers such as } (Exi,k) \neq (Exj,m)$$

  $$PW(FB) < | Of(EXi) + (k \,.\, P(EXi)) - Of(EXj) - (m.\, P(EXj)) - G(EXj) | - WCET\_MAX(FB)$$

- <u>N.B:</u> *If i = j and m = k-1*

  $$| P(EX_i) - G(EX_i) | > AP(FB)$$

Output events characterizations

- The output event EXOi
  - *Of(EXOi) = Of(EXk) + Minexec(j,k)*
  - *P(EXOi) = P(EXk)*
  - *G(EXOi) = G(EXk) + 2.PW(FB) + WCET_MAX(FB) + (WCET(Alg(j,k)) – Minexec(j, k))*

  • Non-Idling policy: Minexec = BCET
  • Idling policy: Minexec = WCET
- Periodic output event EXOi : G(EXOi) ≤ P(EXOi)

Temporal interoperability property (2)

Regular Output events flows

- <u>The schedulability condition 2</u>

  To obtain a periodic output event, the scheduling policy has to respect the condition:

  $\forall EXi$ input periodic event of FB.

$$PW(FB)$$
$$\leq$$
$$(1 / 2) . (P(Exi) - G(Exi) - WCET\_MAX(FBj) - WCET(Alg(j, i)) + Minexec(j, i))$$

- # Conclusion
  - We completely specify a FB behavior
    - Time aspects
    - Priority semantic
    - Simultaneity semantic
    - A model in order to verify
      - Functional properties
      - Extra functional properties
  - We specify the temporal interoperability inside a FBs network
    - Offline scheduling policy
    - A resource scheduler model
    - Schedulability conditions to guarantee such interoperability
- # Future works
  - Propose other policies for the loosing phenomena problem
    - (m, k) condition
  - Automatic generation of a safe offline scheduling
  - Extend our model to take into account
    - Several resources in one or more devices

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TRIO project

http://www.loria.fr/equipes/TRIO/

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