From high-level modelling of time in MARTE to real-time scheduling analysis

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Content

- Structure of the MARTE profile
- A Case study: an ignition control system
- A “step by step” definition of a MARTE model (focus on time and allocation)
- From model to analysis
- Conclusion and ongoing work

Overview of the UML MARTE profile

Specific domain: Real-Time & Embedded Systems

Domain view

- Non Functional Property
- **Time**
- Generic Resource
- Allocation
- …
- Performance analysis
- Scheduling
- …

UML view

- package «profile»
- defining stereotypes
- Model Libraries

Concepts

Software engineering

Aoste contribution

MARTE Time Model : multiform time

- **Time is an explicit model element in MARTE**
  - → Multiple independent TimeBases
  - → Partially ordered set of instants
- **Access to time = Clock**
  - Chronometric clock → **"physical " time; units={s,ms,us,…}**
  - Logical clock → **any repetitive event; units={tick} physicalUnits**
- **Principle: associate Clocks with model elements**
  - Behavioral elements → TimedEvent, TimedProcessing
  - Constraints → TimedConstraint
  - Data types and values → TimedValue

Case study

- **The ignition control system of an automotive engine**
- **Characteristics**
  - **Hard real-time** requirements (deadline, multi-event triggers,…)
  - **Calculate** precisely the instant where the spark plugs of an engine should be fired
  - **Multiple corrections** are applied (knock, warm up and temperature)
    - Natural referential: angular position of the crankshaft

    → **logical clock: crkClk, camCrk**
    - Other referential : engine speed, sensor acquisition

    → **chronometric clocks : IdealClk**

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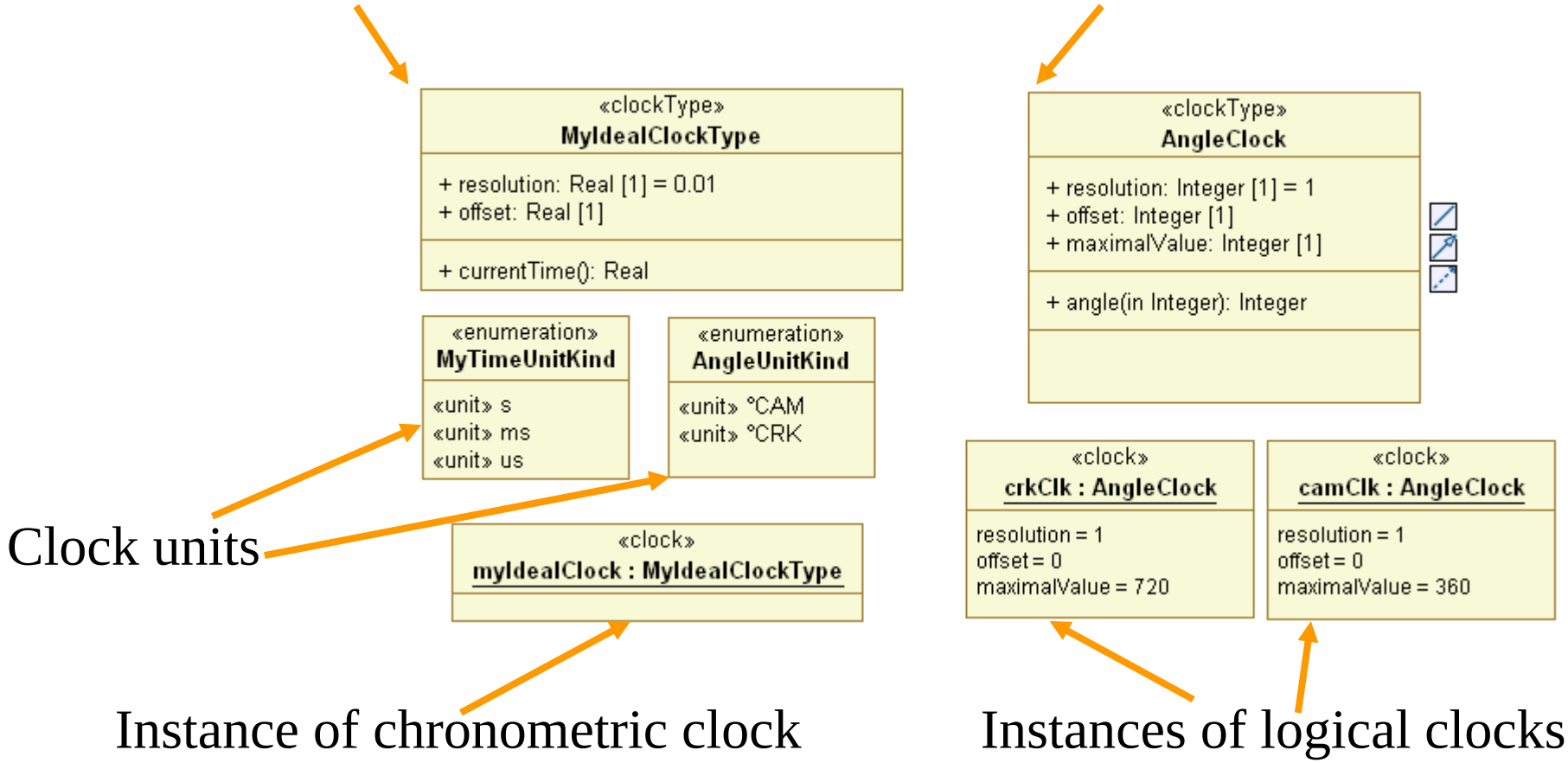
- Overview of the MARTE profile
- A Case study: an ignition control system
- **A "step by step" definition of a MARTE model (focus on time and allocation)**
  - Definition of logical or chronometric clocks, time refinement
  - Modeling of functional parts (timedBehaviour)
  - Modeling of hardware
  - Allocation phase
- From model to analysis
  - and Time refinement
  - Schedulability analysis results applied to models
- Conclusion and ongoing work

Methodological aspects : Clocks as explicit model elements (1/3)

Chronometric clock definition

Logical clockType definition



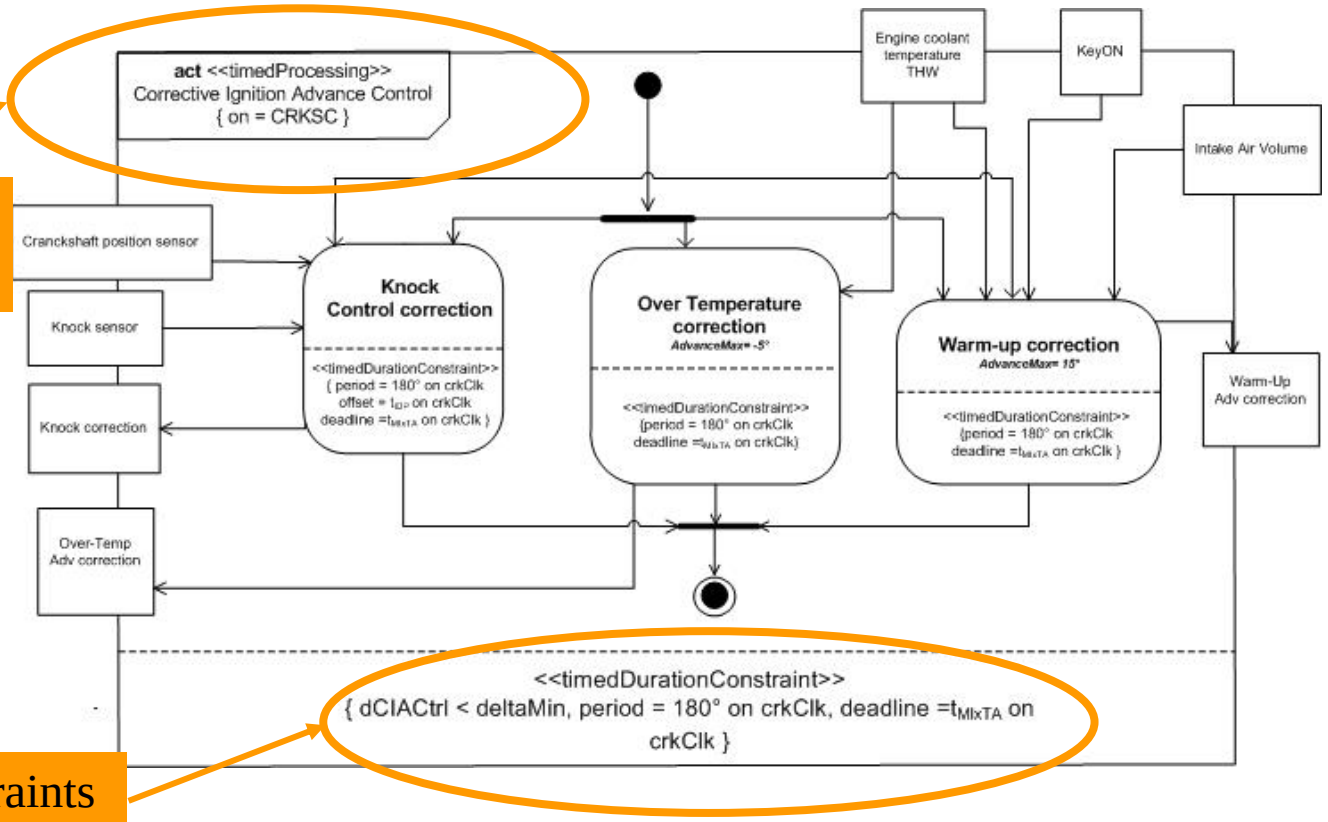
Clock units

Instance of chronometric clock

Instances of logical clocks

Methodological aspects: a timedBehaviour for expressing the dynamic (2/3)

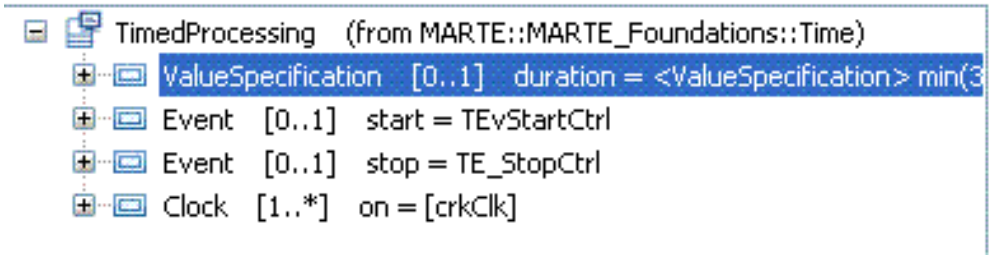
Activity stereoyped by TimedProcessing

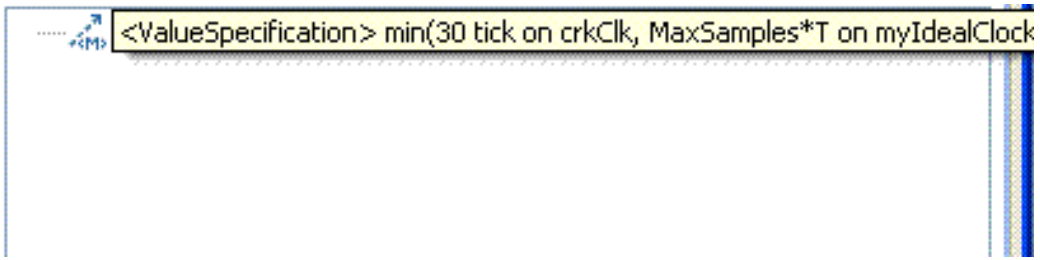


Timed constraints attached to behaviours

Methodological aspects : Non functional characteristics period, offset, deadline (3/3)

- Temporal characteristics attached to functions (deadline, offset, period, WCET)
- In MARTE TimedValueSpecification (Date or Duration)



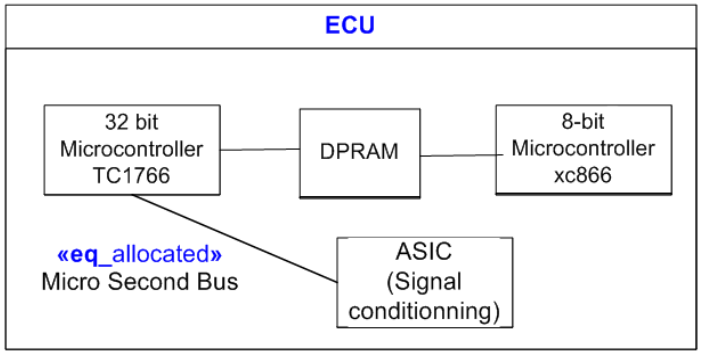


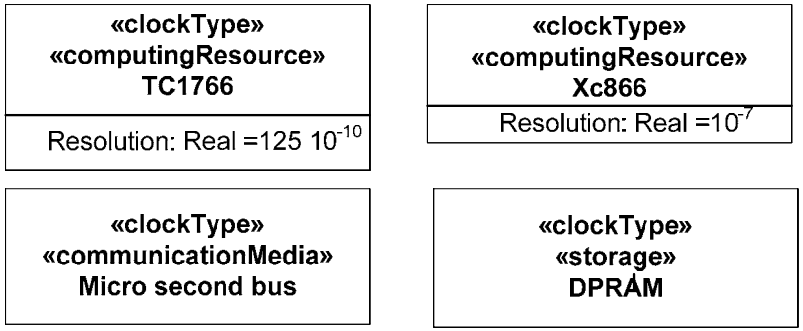
- Possible complex duration expressions with multiple timeBases

$$\text{duration} \prec MIN\left(\begin{array}{l}30\ \text{tick on crkClk},\\ \text{MaxSamples}*\text{T on MyIdealClock}\end{array}\right)$$

Methodological aspects : Allocation (3/3)

- **Model of hardware**
  - Structural view of hardware
  - Temporal characteristics of resources





- **Allocation of functions onto the resources**
  - A new timed value attached to functions : WCET
  - WCET depends on the physical resources (CPU …)

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From models to Scheduling analysis : time refinement (1/2)

- **Relations between clocks : Clock constraints**
  - Clock Constraint Specification Language
  - Two expressions in the example
    - camClk = crkClk filteredby 0b(10)
    - crkClk isPeriodicOn myIdealClock period 1/RPM*6
- **A common notion of time for scheduling analysis**

3 functions/tasks

	Knock	Over Temp	Wam-up
WCET (on TC1766 in ms)	0,5	0,2	0,2
Period(°CRK - *ms*)	180 - *6,66*	180 - *6,66*	180 - *6,66*
Offset date (°CRK - *ms*)	24 – *0,888*	0 - *0*	0 - *0*
Deadline date (°CRK / *ms*)	50 – *1,851*	50 – *1,851*	50 – *1,851*
Deadline duration (°CRK / *ms*)	26 – *0,962*	50 – *1,851*	50 – *1,851*

Temporal characterization of functions

From models to Scheduling analysis : schedulability analysis (2/2)

- **Assumption**
  - RTOS compliant with scheduling analysis policy (preemption allowed)
  - WCET integrates OS overhead

- **Scedulability of tasks Deadline Monotonic algorithm**

$$\sum_{i=1}^{n} \frac{WCET_i}{Deadline_i} \leq n\left(2^{\frac{1}{n}} - 1\right) \text{ with } Deadline_i \leq Period_i$$

- **Results :**
  - Tasks are schedulable with a nominal RPM (engine rotation speed) of 4500 but are not schedulable with a RPM=6000

Conclusion

- **Some methodological aspects on**
  - Using MARTE profile for a high level modeling of time
  - Definition of the main temporal characteristics of functions
  - Integration of physical time (hardware)

- **From models to scheduling analysis**
  - Temporal characteristics and tasks as inputs for scheduling analysis
  - Applying some fundamental results of RT analysis

- **Ongoing & Future works**
  - Simulation of MARTE models (focus on clocks)
  - Model transformation from MARTE models to SynDex

links

- More information about us : AOSTE research team
  www.inria.fr
- MARTE web site www.promarte.org