SYNCHRON 2016

TOWARDS BETTER EMBEDDED SOFTWARE

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Agenda

1. Background
2. State-of-the-art
3. Conceptual deficiencies
4. The link to synchronous languages
5. Requirements of embedded systems
6. Outlook: A new language?

Brandt / Gretz / Grosch | 06.12.2016

I. Background
Our domain

Many Bosch products are driven by embedded software

- Rapid increase in:
  - number of products,
  - their functionality,
  - complexity
- Little progress in:
  - methodology and tools
- We need to advance:
  - Analysis
  - Architecture
  - Implementation
  - Verification

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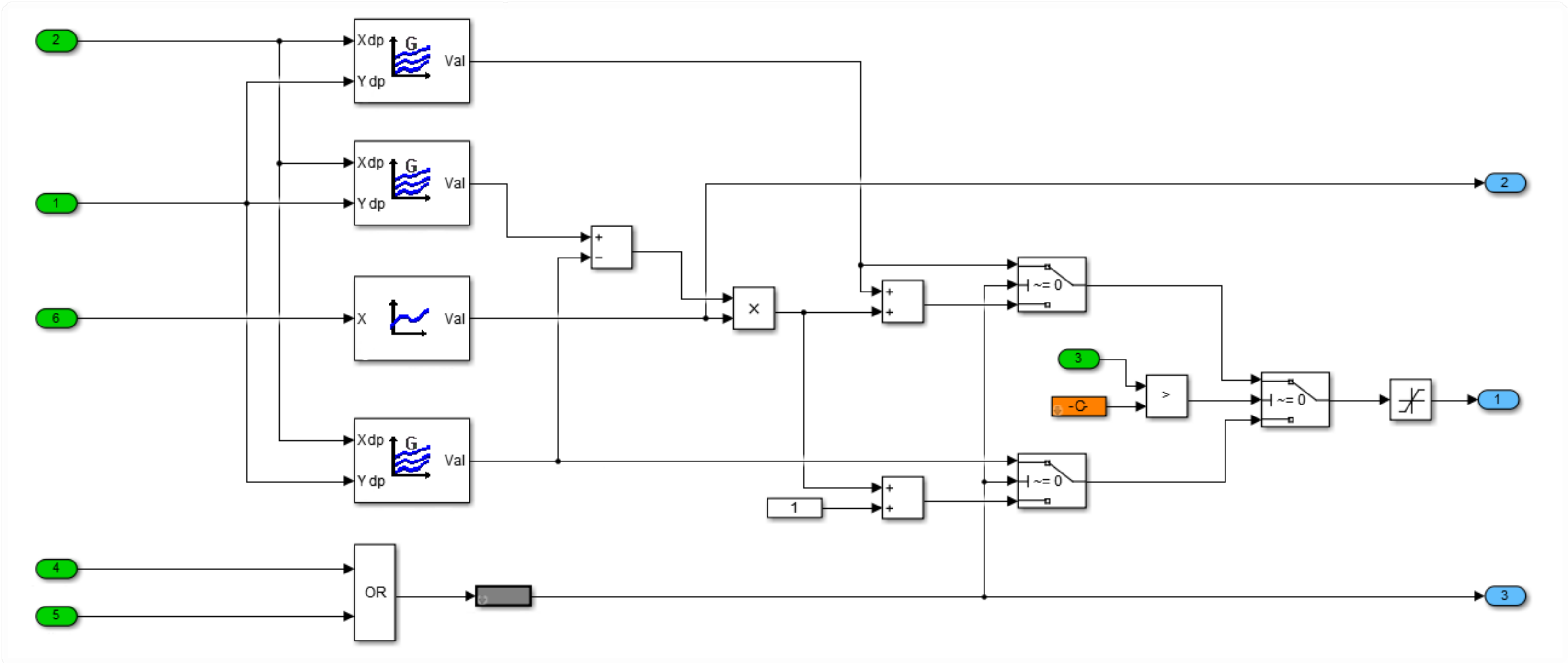
II. State-of-the-art
Programming Frontend

- Assembler → C → Simulink, ASCET



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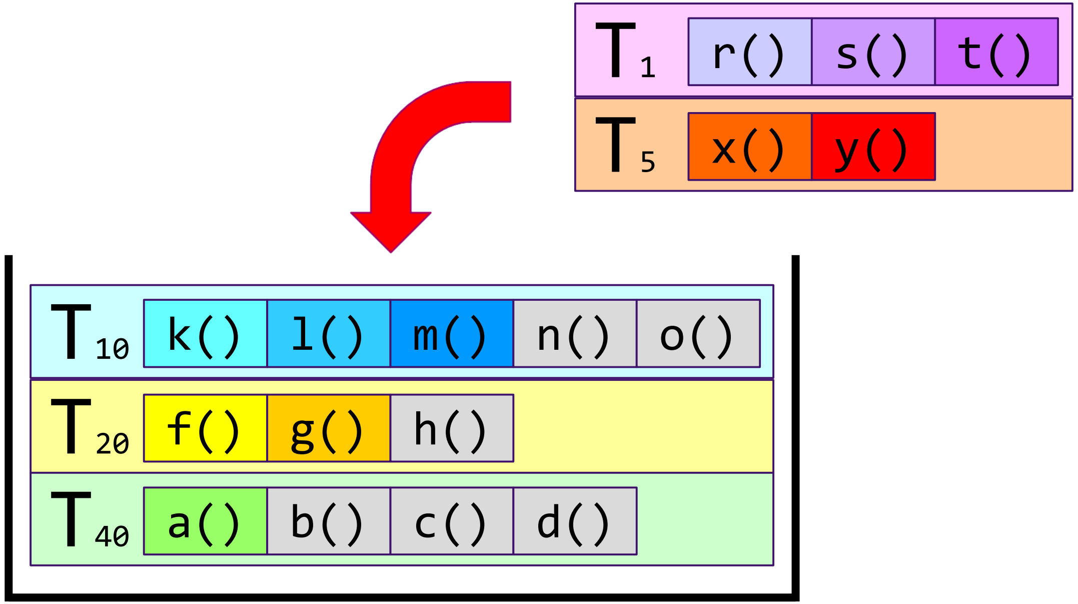
II. State-of-the-art
Deployment Backend

- Runnables: void-void C function
  - `f()` no inputs, no outputs, operates on global variables
- Runnables are ordered in sequence to form a task
  - Sequence T `f()` `g()` `h()`
  - Tasks may be ordered by priority
  - Tasks ≈ clock rates (e.g. 1ms, 5ms, 10ms, …)

- Stack of active tasks
- A running task may be preempted by tasks with higher priority



For more details see: "Real world automotive benchmark for free" by Simon Kramer, Dirk Ziegenbein and Arne Hamann, WATERS 2015

III. Conceptual deficiencies

- Handling concurrency:
  - Who is writing what variable and when?
  - Ordering of runnables and tasks determined by a separate task list in XML
    - Implicitly introduces prev and current accesses without ever being documented
- State machine behaviour is either implicit or formulated in a separate monolithic model
- Nondeterminism:
  - Above ordering has no formal criteria
  - Communication between concurrent threads is non-deterministic

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III. Conceptual deficiencies
Effects of deficiencies

- Adding new software is hard
- Most effort is spent in:
  - Reverse engineering to find out who is writing what variable and when
  - Composition of software components, requiring lots of meta data about side effects, timing constraints, …
- Lack of software qualities such as:
  - Determinism & testability
  - Readability
  - Flexibility (refactoring!)
  - Modularity

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IV. The link to synchronous languages
Why we are here

- We believe we can benefit greatly from the synchronous programming approach:
  - Behaviour over time
  - Preemptions and mode switches
  - Structured programming of state machines
  - Causality of concurrent functions
- We hope your research may benefit from industrial challenge
- So where is the challenge?

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V. Requirements
Clear focus

▶ Software	Not hardware
▶ Embedded	Not “IT”-level software
▶ Reactive	Trigger-response execution
▶ Real-time	Time is functional, not a performance measure
▶ Resource-constrained hardware	No heap allocation, garbage collection
▶ Scale to software with millions lines of code	Not “wrist watch”

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V. Requirements
Domain orientation

- Control intensive systems
- Intertwined functionality
- Computations and switching behaviour
- Preemptions
- Causality

Relaxed notion of causality is sufficient for software
= concurrent processes + shared variables + barriers!

Synchronous programming = Unique writer and
write before read between each pair of barriers.

V. Requirements
Compatible with the past and future

- Integration of legacy code
- Integration in legacy code
- Support separate compilation
- Address deployment on multi-core platforms
- Program across threads, cores maintaining guarantees such as causality

V. Requirements
Deployment

- Efficient code generation .... No definitive consensus yet?
- Safe code generation .... Runtime errors shall be impossible on a final system
- Integrate synchronous “execution shell” with existing real-time OS environments
- Low level mapping to cores and tasks

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V. Requirements
Developer orientation

▶ Readable programs	Programs are mostly read, sometimes adapted and almost never written from scratch
▶ Crystal clear semantics	Make it hard to write nonsense, make it obvious what any piece of code does
▶ Express stateflow in control flow	
▶ Provide structured data types (arrays, structs, enums)	These cannot be disintegrated into primitives
▶ Enable structuring, information hiding	Structures cannot be just macros that are instantiated and inlined
▶ Provide a safe and modern type system	Physical units, sum types

V. Requirements
Testing and verification

- Easy testing ……………… Write tests in the same language and compose concurrently with production code
- Integration with existing simulation frameworks ……………… E.g.: Simulink, Functional Mockup Interface
- Generate verification conditions for abstract interpreters ……………… Lots of assertions (no 0-division, no out-of-bounds access, ...) are never specified by the programmer but are trivial to generate and significantly help to find bugs

V. Not requirements
By focusing we gain a few degrees of freedom

- What we do not need
  - Hardware related issues
  - Single value per tick
  - Reordering of commands
  - Fine grained causality based on logical constructiveness or dynamic analyses
  - Full range of preemption expressions

- And hence no
  - Schizophrenia
  - Fix point computations
  - Intricate surface/depth compilation

VI. Outlook
Do we need something new?

- No off-the-shelf solution available which meets above requirements
- Theoretically most requirements are straight forward
- Some however are not
  - True parallelism
  - Deployment
  - OO, references vs. causality

- We have a vision that all requirements together lead to a new language with a new compiler and IDE that support (most of) the above
- And we believe this will significantly improve the implementation methodology of embedded systems
- And there is the first practical evidence that a paradigm shift may be of interest to real-life developers

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