Event Driven Real-Time Programming

CHESS Review
University of California, Berkeley, USA

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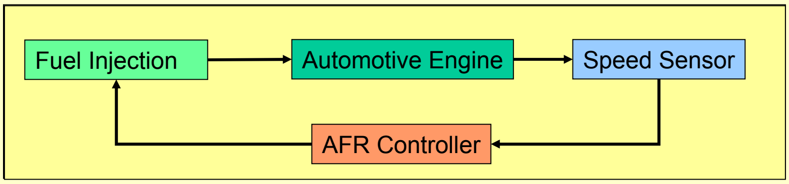
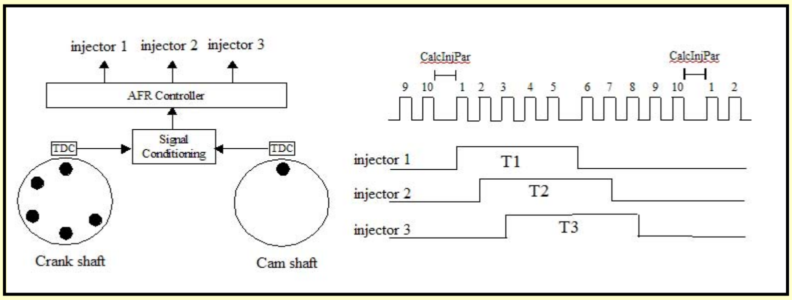
Overview

- Introduction
- Language Features
  - The LET model
  - Language Constructs
  - Event Scoping
- Analysis
- Implementation
- Ongoing Work

Control System





Implementation Strategies

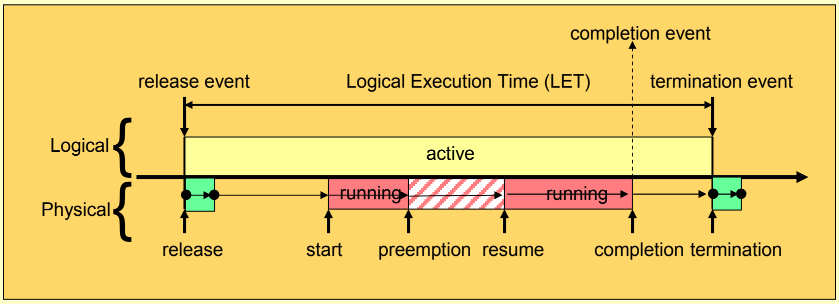
- Traditional
  - Uses priorities to specify the relative deadlines of software tasks
  - Supports efficient code generation based on scheduling theory
  - Run-time behavior is highly non-deterministic
- Synchronous Languages
  - Esterel, Lustre, Signal
  - Based on synchrony assumption: task computation takes negligible execution time
  - Shows deterministic behavior
- Timed Languages
  - Based on Logical Execution Time (LET) for tasks
  - Giotto
    - Time Triggered
  - xGiotto
    - Event Triggered
    - Scoping of events

Logical Execution Time

The logical and physical execution times are depicted below. The events controlling a task behavior are:

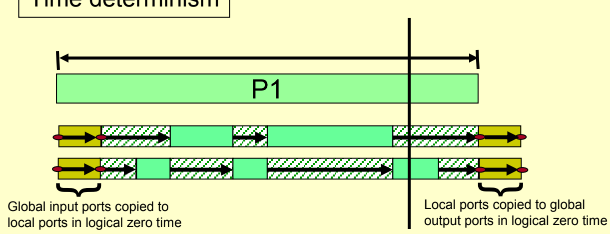
Event generated by the environment:
- release
- termination

Events generated by the platform:
- start
- preempt
- resume
- completion



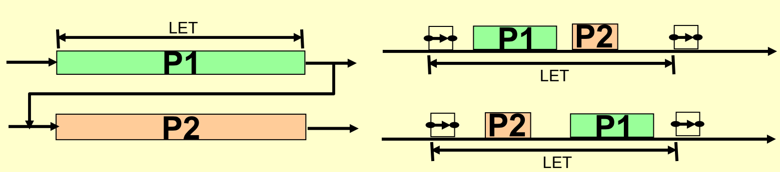
Logical Execution Time

Time determinism



Value of output port remains invariant at any instant independent of execution pattern

Value determinism



Reactions and Triggers

- A trigger maps an event to a reaction
  - When the event occurs the reaction is invoked
- A reaction defines
  - New triggers
  - A termination event
- Events of a reaction block are the events of its triggers and the termination event
  - A reaction block defines a scope for its events
- When a trigger is invoked
  - The events of the new reaction block are enabled (active)
  - The events of the callee reaction block become passive (inactive)

Reaction Block

Reaction Name

```
react R1 {
    when [e2] react R2;
    when [e3] react R3;
} until [e7];
```

Triggers

Until Event

Events of R1: e2, e3, e7

Scope of e2, e3, e7: R1

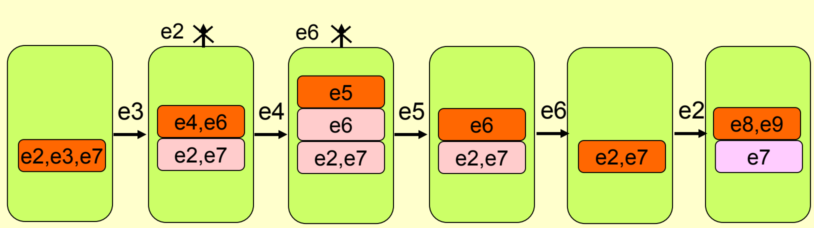
Reactions and Triggers

```
react R1 {
    when [e2] react R2;
    when [e3] react R3;
} until [e7];
```

```
react R3 {
    when [e4] react R4;
} until [e6];
```

```
react R4 {
} until [e5];
```

```
react R2 {
    when [e8] react R5;
} until [e9];
```



Tasks

- Tasks instances are defined by release statements
- Tasks instances
  - released with the invocation of the reaction block
  - terminated with the termination of the reaction block
- LET of the task is given by the life-span of the reaction block

Task Name

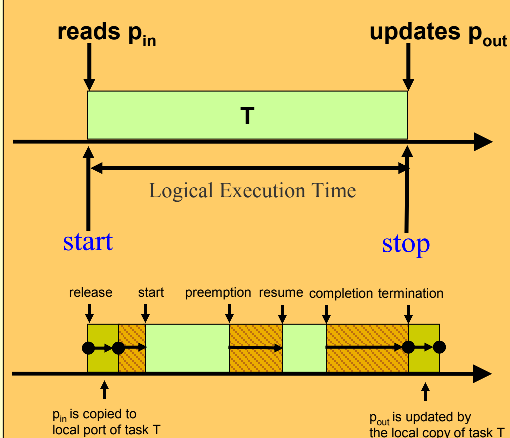
Input Port

Release Statement

```
react R1 {
  release t1 (i1) (o1);
  when [e2] react R2;
  when [e3] react R3;
} until [e7];
```

Output Port

Releasing Tasks




```
port
   pin;
   pout;
event
   start;
   stop;
task T (i) output (o)
   {/* compute */}
react R {
   release T(pin)(pout);
} until [stop]
{ when [start] react R;}
```

Tasks

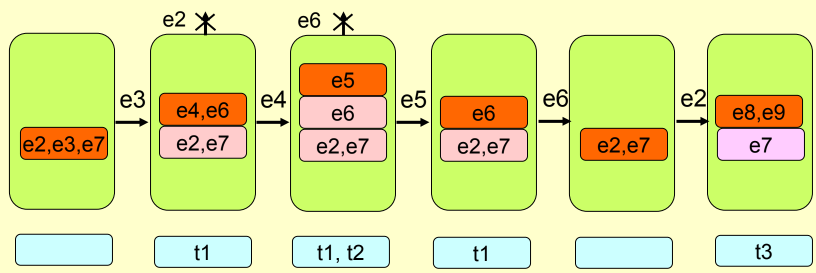
- Tasks are released with the invocation of the reaction block
- Tasks are terminated with the termination of the reaction block

```
react R1 {
    when [e2] react R2;
    when [e3] react R3;
} until [e7];
```

```
react R3 {
    release t1;
    when [e4] react R4;
} until [e6];
```

```
react R4 {
    release t2;
} until [e5];
```

```
react R2 {
    release t3;
    when [e8] react R5;
} until [e9];
```



Handling Events

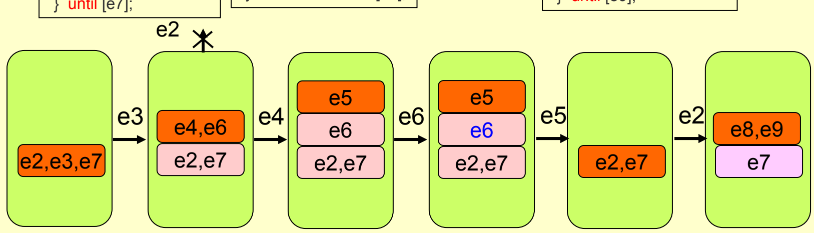
- A reaction block defines a scope: this implicitly denotes the scope of an event
- When an active trigger is invoked, the called reaction becomes the active scope and the caller reaction, the passive scope
- The event of a passive scope can be
  - Ignored (**forget**)
  - Postponed until its scope becomes active again (**remember**)

```
react R1 {
    when [e2] react R2;
    when [e3] react R3;
} until [e7];
```

```
react R3 {
    when [e4] react R4;
} until remember [e6];
```

```
react R4 {
} until [e5];
```

```
react R2 {
    when [e8] react R5;
} until [e9];
```



Parallelism

- A trigger may invoke multiple reaction blocks in parallel.
- When the trigger is invoked all the reactions become active simultaneously.
- The parent block is active only when all the parallel reaction blocks have terminated.

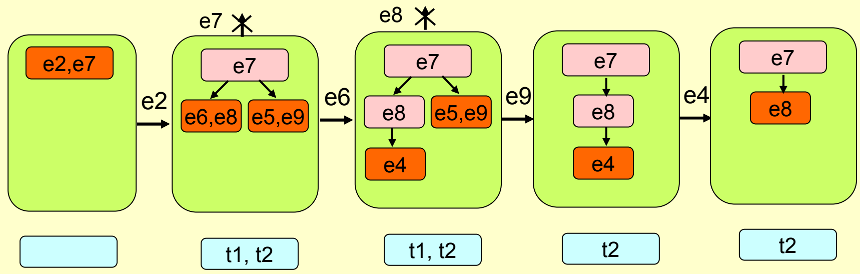
```
react R1 {
   when [e2] react R2 || R3;
} until [e7];
```

```
react R3 {
   release t1;
   when [e5] react R5;
} until [e9];
```

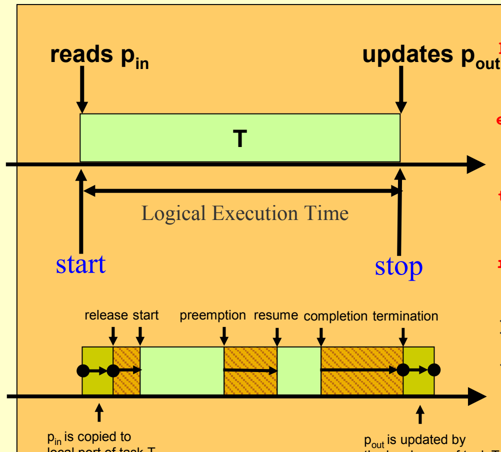
```
react R2 {
   release t2;
   when [e6] react R6;
} until [e8];
```

```
react R6 {

} until [e4];
```



Environment Assumption




```
port
   pin;
   pout;
event
   start;
   stop;
task T (i) output (o)
   {/* compute */}

react R {
   release T(pin)(pout);
   when [now] react {} until [3ms];
} until [3ms]stop]

{ when [start] react R; }
```

xGiotto: Basic Constructs

- Reaction Blocks
  - Basic programming blocks in xGiotto
  - Consists of release statements and trigger statements along with an termination information
  - Releases tasks and invokes triggers
    - react {reaction block} until [event];

```
reaction() {
    release task1 (i1) (o1);
    release task2 (i2) (o2);
    when event1 react block1;
    whenever event2 react block2;
} until event;
```

- Release Instruction
  - Tasks are released with the invocation of the reaction block
  - Tasks are terminated with the termination of the reaction block
    - release task (input ports) (output ports);
- Trigger Statements
  - Defines the invoking action associated with an event
    - when [event] reaction block;
  - Repetition construct using whenever

Structuring Events

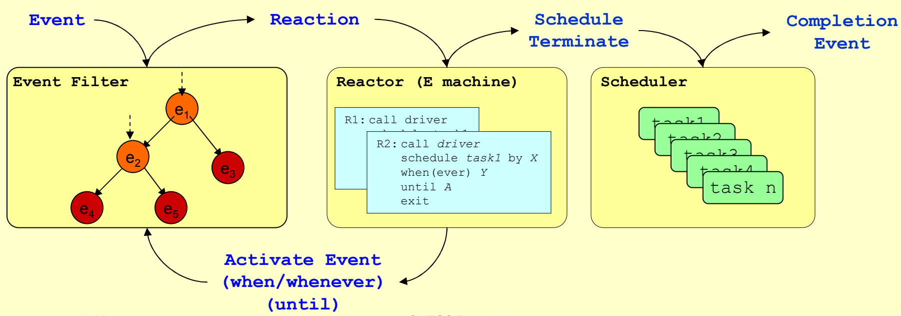
- Scoping of events
  - A reaction block defines a scope: this implicitly denotes the scope of an event.
  - When an active trigger is invoked, the called reaction becomes the active scope and the caller reaction, the passive scope.
  - The tree of scopes and the state of program variables denotes the state of the program.
- Handling of events (of a passive scope)
  - It may be ignored (**forget**)
  - It may be postponed until its scope becomes active again (**remember**)
  - It may disable trigger statements of all descendent blocks and thus speeding up their termination (**asap**)
- Invoking reactions in parallel
  - Wait-parallelism
  - Asap-parallelism
- Embedding Environment Assumption
  - Event calculus

The Program Flow

Event Filter:
The Event Filter implements the event scoping mechanism and filter the incoming event. It determines which event needs to be reacted upon depending upon the event qualifiers – forget, remember or asap .

Reactor:
The Reactor executes the specified reaction and activates new events (when/whenever/until) and activates and terminates tasks (release).

Scheduler:
The Scheduler chooses from the active tasks, a task to be executed on the given platform (CPU). The scheduler generates an event at task completion.



AFR Controller

port
/* fuel ports */
/* pulse ports */

event
teeth; synch; stop;

task set { /* opens the valve */ }
task reset { /* closes the valve */ }
task dec {/* pulse generation */}

task CalcFuelInj
{/* fuel parameter computation */}

```
react channel2 {
  react { } until [5ms : teeth];
  when remember [5ms : teeth] react {release set} until [ms];
  react
    loop react {release reset; dec;  } until [ms];
} until asap [50ms : 9teeth]
```

```
react calcFuel { release CalcFuelInj; } until [10ms : teeth];
```

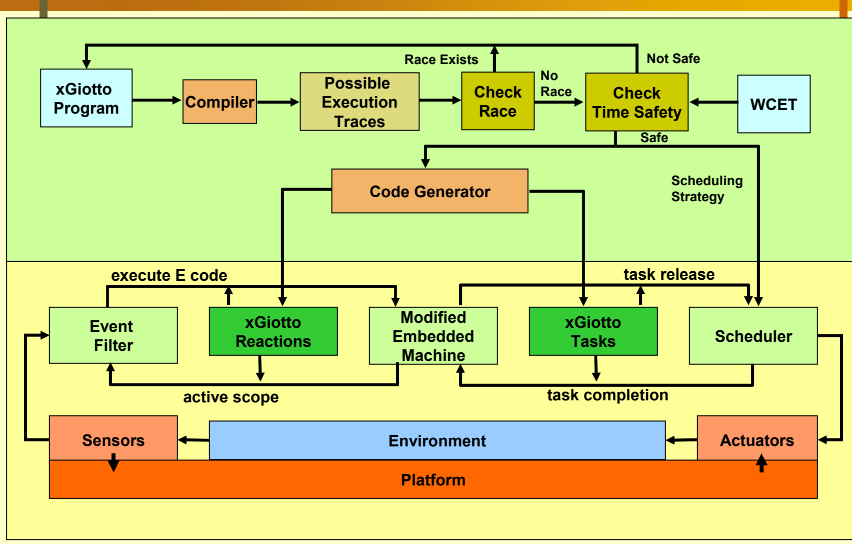
```
react controller {
   react calcFuel;
   when remember [teeth]
        react channel1 ||  react channel2  || … ;
} until remember [10teeth]
```

```
react start {
   whenever remember [10teeth] react controller;
} until [stop];
```

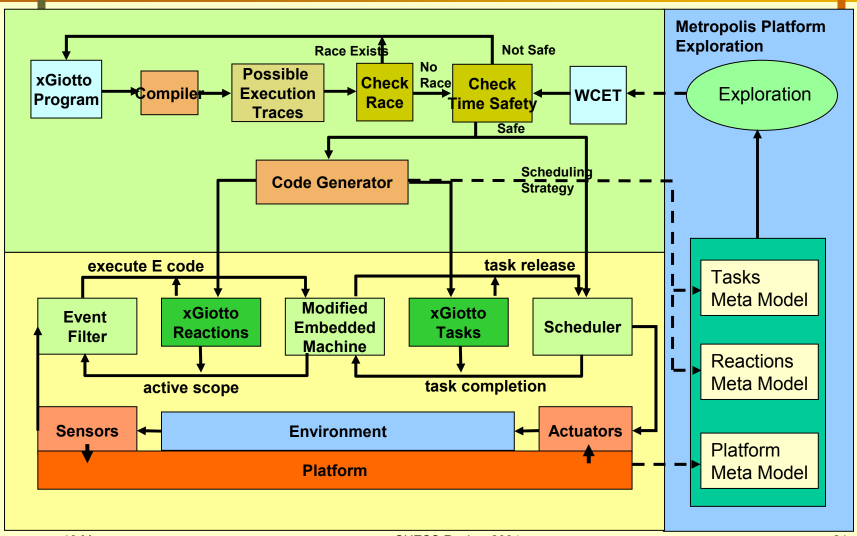
Analysis

- Platform independent
  - Race Condition Detection
    - Verifying whether a port may be updated by multiple task invocations and thus leading to non-determinism
  - Resource Size Analysis
    - Predicting the run-time memory requirements for executing an **xGiotto** program: the bound on the size of the event filter and scopes (trigger queue size and active task set size).
- Platform dependant
  - Schedulability Analysis
    - Ensuring that all the task invocations get access to the executing platform at least equal to their worst-case-execution times before their termination

Implementation



Implementation



Ongoing Works

- Implementation
  - Generate code
    - Embedded Virtual Machine code
    - Metropolis Meta-model
  - Porting to RTOS
    - EVM, JVM, OSEK
  - Case studies
    - Porting AFR controller on OSEK
- Analysis
  - Defining the run-time system for xGiotto
  - Schedulability check in time polynomial to the size of the program
- Future Direction
  - Sub-classes of xGiotto
    - Definition, inter relation and effectiveness towards event-driven programming
  - Type Checking

Thank You !