On Designing a Target-Independent DSL for Safe OS Process Scheduling Components

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Overview

- Introduction to Domain-Specific Languages (DSLs).
- Our proposal for DSL design.
- Instantiation in the Bossa DSL for process scheduling.
- Conclusions.

Domain-Specific Languages (DSLs)

DSL: A language dedicated to a particular domain.

- Captures a family of programs.
- Provides high-level domain-specific abstractions that
  - Simplify programming.
  - Enable verifications, optimizations.

Useful when:

- Programming within the program family is often needed.
- Programming within the program family requires highly specialized knowledge.

Examples: lex, yacc, SQL, languages for graphics, Web programming, etc.

Our target domain: process scheduling

Process scheduling: How an OS selects a process for the CPU.

- Many scheduling policies (round-robin, rate monotonic, etc.).
- Policies form a program family.
- No policy is perfect for all applications.

Implementing a scheduler requires:

- Understanding the scheduling policy.
- Understanding the target OS.
  - Any error can crash the machine.

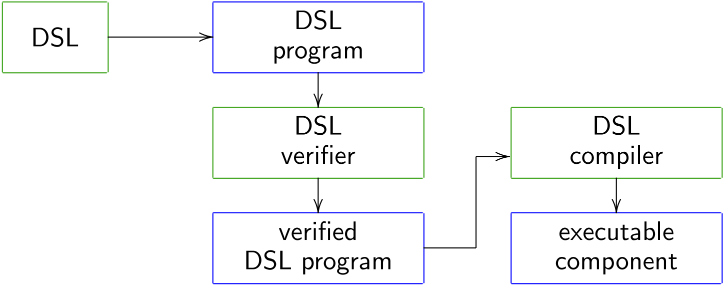
$\Rightarrow$ An ideal DSL target ...

- Bossa [Muller, Lawall, et al., EW2002, ASE2003, PEPM2004]

Creating a DSL

A domain expert uses domain expertise to [Consel, Marlet, PLILP'98]:

- Select language abstractions.
- Develop a language syntax.
- Implement language support (verifier, compiler, etc.)



Problem: Multiple kinds of expertise may be needed.

Expertise needed to create a DSL for process scheduling

Expertise in scheduling policies:

- Liveness, bounded response time, etc.
- What kinds of operations are needed to provide these properties?

Expertise in operating systems:

- How does existing scheduling code work?
- What existing scheduling code should be replaced?
- What invariants must scheduling code maintain?

Problem: Expertises required at different times.

Our proposal

Divide the role of the domain expert:

- Scheduling expert: Expert in the program family.
  - Identifies relevant language constructs.
- OS expert: Expert in each specific execution environment.
  - Identifies relevant OS properties.

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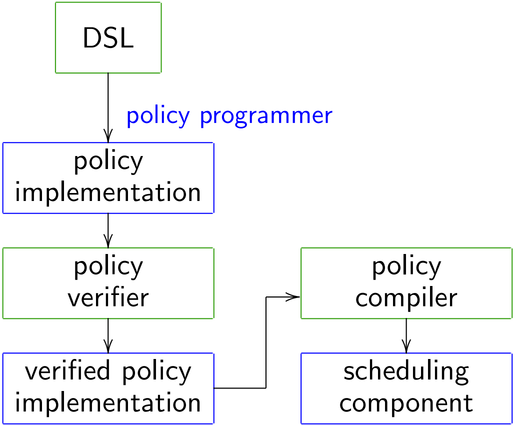
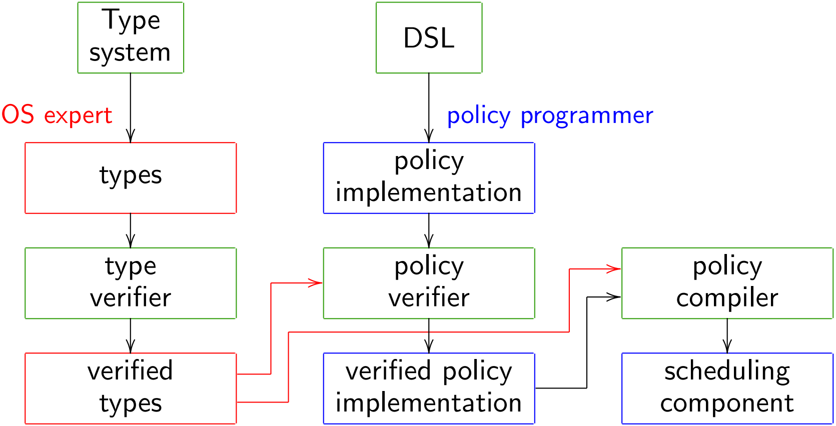
Introduce a type system:

- Developed by the scheduling expert based on an analysis of the range of relevant properties.
- Used by the OS expert to describe OS properties.
- Types used in verifying and compiling DSL programs.

Instantiation in the Bossa DSL



Instantiation in the Bossa DSL



Issues

- Can relevant properties be expressed in a concise and understandable way?
- Can type information be used to detect errors?
- Can type information improve the result of compilation?

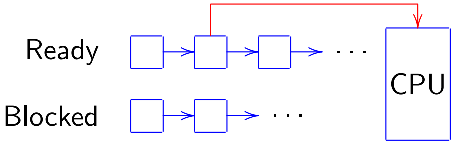
The Bossa DSL, in more detail

- The scheduling domain.
- Contribution of the scheduling expert
- Contribution of the OS expert
- Tying things together: the verification process.

The scheduling domain

Goal of process scheduling:

- Elect a new process.
- Only ready processes are eligible.



A scheduler must:

- Elect an eligible process.
- Adjust process states in response to kernel events.

Contribution of the scheduling expert

Language infrastructure (OS independent)

- Syntax
  - main elements: process states and event handlers
- Type system
- Verifier
- Compiler

Process states

```
states = {
    RUNNING    running    : process;
    READY      ready      : select queue;
    READY      expired    : queue;
    BLOCKED    blocked    : queue;
    TERMINATED terminated;
}
```

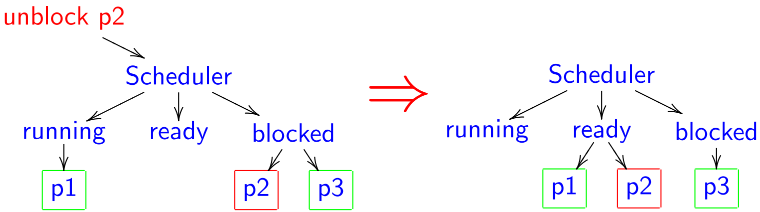
States: running, ready, etc.

State classes: Describe state semantics:

- RUNNING: the state of the running process
- READY: states containing eligible processes
- BLOCKED: states containing blocked (ineligible) processes
- TERMINATED: a dummy state for terminating processes

Event handlers

```
On unblock.* {
  if (e.target in blocked) {
    e.target => ready;
    if (!empty(running)) {
      running => ready;
    }
  }
}
```



Contribution of the OS expert (Linux 2.4)

Events:

bossa.schedule, block.*, unblock.preemptive.*, unblock.nonpreeptive.*, ...

Interrupt events: unblock.preemptive.*, unblock.nonpreeptive.*, ...

Event sequences: block.* $\xrightarrow{u}$ bossa.schedule, ...

Type rules:

- unblock.preemptive.*:
  - `[tgt in BLOCKED] -> [tgt in READY]`
  - `[p in RUNNING, tgt in BLOCKED] ->`
    `[{p, tgt} in READY]`
  - `[tgt in RUNNING] -> []`
  - `[tgt in READY] -> []`
- 11 events, 60 rules for Linux 2.4.

Tying things together

Verifier and compiler:

- Implemented by the scheduling expert.
- Configured with information provided by the OS expert.

Verifier:

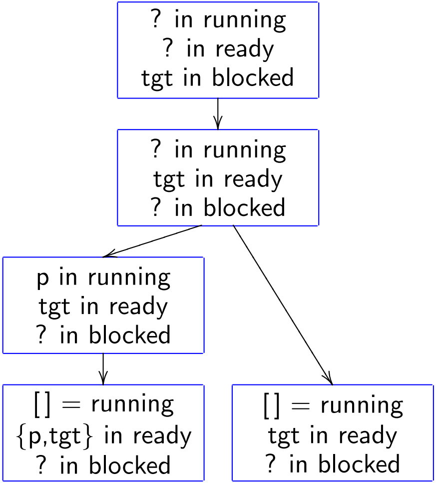
- Checks that all handlers are present.
- Checks that handlers implement allowed transitions.

Compiler:

- Generates C code.
- Uses information collected by the verifier.

Verification example

```
On unblock.preemptive.* {
  if (e.target in blocked) {
    e.target => ready;
    if (!empty(running)) {
      running => ready;
    }
  }
}
```



Verification with respect to:
`[tgt in BLOCKED] -> ...`

Matches:
```
[p in RUNNING, tgt in BLOCKED]->
  [{p, tgt} in READY]
```

`[tgt in BLOCKED] -> [tgt in READY]`

Conclusions

Multiple kinds of expertise required to implement a DSL.

- May not all be available at the same time.

For scheduling, we propose:

- A scheduling expert.
- An OS expert.
- A type system to connect them.

DSL can be constructed so that the contribution of the OS expert can be usefully exploited.

Availability

- Implementation in Linux 2.4, with and without high-resolution timers.
- Example policies and applications.
- Teaching lab, based on Knoppix.
- MPlayer demo.

http://www.emn.fr/x-info/bossa/