Language support for AOP

AspectJ and beyond

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Plan

- AOP and AspectJ
- AspectJ: end of story?
- Beyond AspectJ

I. AOP and AspectJ

Defining characteristics of AOP?

- **Quantification**: modularization of crosscutting concerns
- **Obliviousness**: non-anticipation; incremental development

$\Rightarrow$ Tackle crosscutting in large-scale applications throughout the software life cycle

More probably later from Bob . . .

What's new? (1)

- What about **computational reflection**?
  - 3-Lisp, CLOS, Reflex [Tanter et al., OOPSLA'03], . . .
  - General enough reflective system can "emulate" AOP systems
  - Difficult to understand
  - Performance issues
  - Semantics issues, lack of correctness guarantees

What's new? (2)

- What about **transformation systems**?
  - General enough transformation system can "emulate" AOP systems
  - SOOT, Recoder, CIL, . . .
  - Difficult to understand
  - Correctness properties difficult to handle

Yes, it is! (in a sense)

Goals for AOP

- Provide abstractions general enough to modularize (some or all) concerns.
- Be specific enough to make such modularization understandable, tractable and amenable to testing, analysis, verification of properties.

AspectJ in one slide

Base program: `critical`, `access`

AspectJ in one slide

```
pointcut accesses(Base r): call(void Base.acc(int)
  && target(r)
  && cflow(call(void Base.crit(int))));
```

AspectJ in one slide

```
pointcut accesses(Base r): call(void Base.acc(int)
  && target(r)
  && cflow(call(void Base.crit(int))));
void around(Base r):  critAcc(r) {
  calls++;
  if (ok()) proceed(r);
}
```

AspectJ in one slide

```
aspect ProfBar pertarget call(void Base.acc(int)) {
  int calls = 0;

  pointcut accesses(Base r): call(void Base.acc(int)
    && target(r)
    && cflow(call(void Base.crit(int))));
  void around(Base r):  critAcc(r) {
    calls++;
    if (ok()) proceed(r);
  }
}
```

AspectJ in one slide

```
aspect ProfBar pertarget call(void Base.acc(int)) {
  int calls = 0;
  static int Base.calls = 0;
  pointcut accesses(Base r): call(void Base.acc(int)
    && target(r)
    && cflow(call(void Base.crit(int))));
  void around(Base r):  critAcc(r) {
    calls++;
    if (ok()) proceed(r);
  }
}
```

Characteristics of AspectJ

- \+ Join points
- \+ Pointcuts
- \+ Advice
- \+ Aspects
- \+ Inter-type declarations
- +– Aspect instantiation (`coarse-grained`)
- +– Aspect activation (`on/off`)
- +– Aspect composition (`dominate`)

II. AspectJ: end of story?

- Other characteristics of aspect languages
- Other base languages, execution environments
- More expressive pointcut languages

Other characteristics of aspect languages

- Aspect instantiation
  E.g., runtime instances, Kevin's talk
- Aspect activation
  E.g., enable/disable aspects at runtime
- Aspects of aspects
  E.g., layered aspects, Kevin's talk
- Aspect composition
  E.g. for conflict resolution
- Weaver semantics
  E.g., no aspects of aspects

A world outside Java?

- Crosscutting concerns in large (legacy) C applications
- Ex.: optimization of web caches without cache flushes
- New aspect languages for expression of complex context conditions

A principled view on AO for programming

- Matthias F.:
  1. “CS = reconcile hacking with Math”
     - Hacking: property-free programming
     - Math: freewheeling property proving
  2. “AOP currently has no valid foundation, is nothing but hacking”
  3. “AOP cannot be firmly grounded and reasonably used because of destruction of encapsulation properties”

One (my) not-so principled answer

1. “CS = reconcile hacking with Math”
   Ok.
2. “AOP currently has no valid foundation”
   Essentially ok, but first (small) results on aspects: formal semantics, interaction analysis, modularity and aspects.
3. “AOP cannot be reasonably used”
   Pragmatic answer: Application of AOP to interfaces (e.g., integration aspects for distributed middlewares)

Other pointcut languages (1)

- **Stateful pointcuts** (explicit state in pointcuts)
  - Sequence pointcuts:
    Ex.: protocol translation and bug correction
  - Temporal logic pointcuts:
    Ex.: manipulation of Linux kernel code
  - Regular expression pointcuts:
    Enable interference analysis among aspects

Other pointcut languages (2)

- AOP and distributed applications
  - Often integration/configuration of existing distribution platforms (see Kevin's talk)
    $\Rightarrow$ distribution implicit to aspects
  - **Remote pointcuts** [Nishizawa et al., AOSD'04]: explicit `hosts`, advice server
  - Trade-off: hide complexity vs. flexibility
- **Data-flow pointcuts** [Masuhara, Kawauchi; APLAS'03], e.g., for security enforcement. Efficiency realization

III. Beyond AspectJ

1. Dynamic aspects for C system-level applications
2. Temporal logic pointcuts for Linux kernel evolution

1. Dynamic aspects for C system-level applications

- Software evolution frequently to be performed on running systems (e.g., high-availability servers)
- Ex. concerns in a web cache
  - Modification of caching policies
  - Optimizations (e.g., protocol transformations TCP$\longrightarrow$UDP)
  - Bug corrections
- Some large applications:
  Open-source web-cache “squid”: 9 MB of source

Ex.: explicit sequences for buffer overflows

- Aspect language with explicit sequences

$$\begin{aligned}
&\texttt{seq}(\ \texttt{call}(\text{void} * \text{malloc}(\text{size_t})) \\
&\qquad \&\& \ \texttt{args}(\mathit{allocatedSize}) \ \&\& \ \texttt{return}(\text{buffer})\ ; \\
&\quad \texttt{write}(\mathit{buffer}) \ \&\& \ \texttt{size}(\mathit{writtenSize}) \\
&\qquad \&\& \ \texttt{if}(\mathit{writtenSize} > \mathit{allocatedSize}) \\
&\qquad \texttt{then}\ \mathit{reportOverflow}();\ * \\
&\quad \texttt{call}(\text{void free}(\text{void}*))\ )
\end{aligned}$$

Aspect language

- Primitive pointcuts: calls and variables accesses (to global and local variables)
- `cflow` for nested calls (like AspectJ)
- Sequences with
  - Conditionals over data
    Principally equalities (e.g. over file handles)
  - Means for ressource handling
    Optimize ressource usage (e.g., reuse of file handles)

Realization: the Arachne system

- Dynamic aspect application for C without program interruption
  `www.emn.fr/x-info/arachne`
- Rewrite binary code on the fly to weave (and deweave) aspects
- Current weaving semantics excludes nested aspects
  Simplified implementation, somewhat more efficient
- [Ségura et al, AOSD'03] [Fritz et al, AOSD'05]

2. Temporal logic pointcuts for Linux kernel evolution

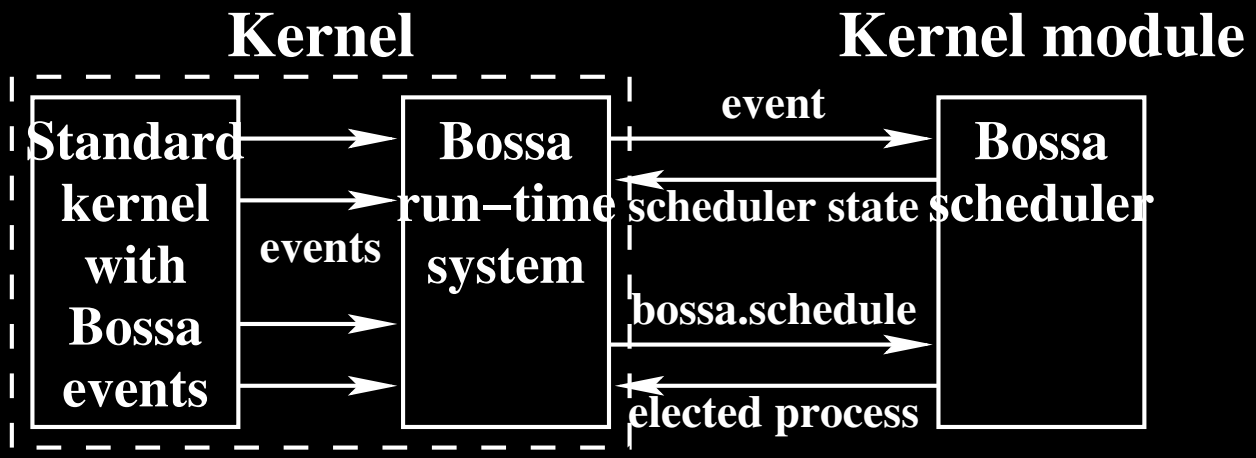
- Problem: support extensions of the Linux kernel over a range of kernel versions
  E.g., over one major version number
- Ex.: support application-specific schedulers
  E.g., for multi-media streaming
- Context: integrate an existing system for scheduler development with the kernel

Bossa: new schedulers for plain old Linux

- Bossa: system for scheduler development `www.emn.fr/x-info/bossa`
- DSL: definition of scheduling policies
- Support runtime for hierachical, prioritized, etc., schedulers
- Runtime overhead $<$ 5%

Bossa architecture

- Events mediate between (instrumented) kernel and Bossa runtime, which supports policies

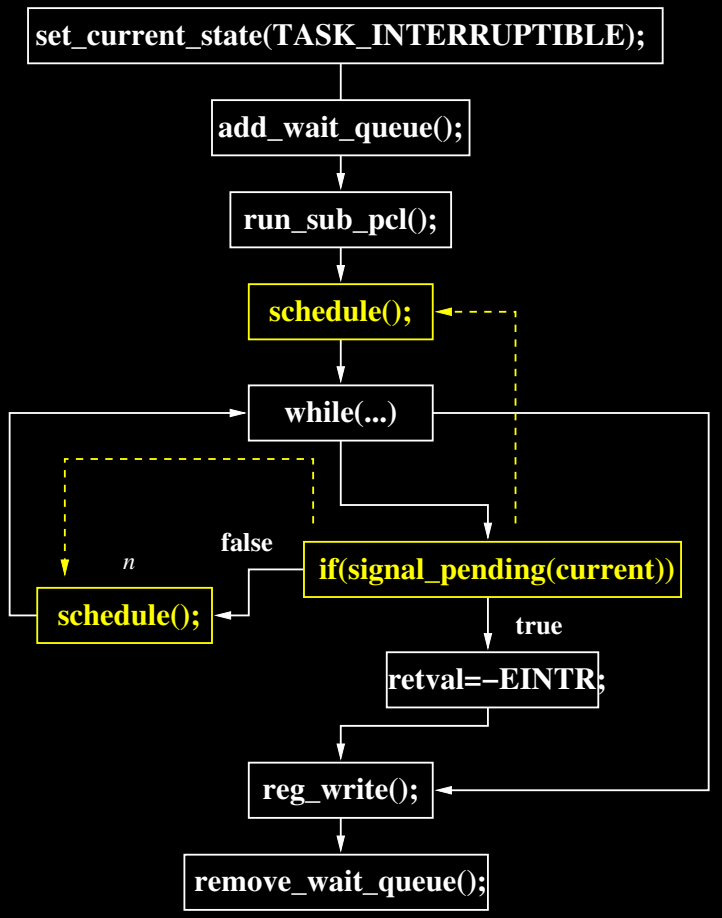


Mediation through events crosscuts the kernel

- Instrument kernel code + drivers (˜ 100 MB source code)
- Instrumentation for Bossa:
  - ˜ 400 instructions changed in about 150 files
- Previously manually done for Linux kernel 2.4
- Can we do better with aspects?

Problem: context dependencies

- Generate events for `schedule` instructions
- Other instructions relevant (e.g., thread state, `yield`)
- Problem: thread context implicit
- Explicit context dependencies vs. efficiency



Solution: temporal logic pointcuts

- Use temporal predicates to express control-flow relationships

n : Rewrite(n, `schedule_running`)

If $n \vdash AX\triangle(A\triangle(\neg$changeOfState() U changeToRunning()$))$

"Change current instruction to `schedule_running` if for all backword pathes starting from the predecessor node, all backward pathes change to running without previous changes to the state."

Results

- Transformational system for Bossa integration: 25 rules
- Implementation based on CIL yields exact instrumentation
  $\Rightarrow$ no overhead to manual instrumentation
- 6 bugs of manual instrumentation detected
- [Åberg et al., ASE'03]

Conclusion

- AOP is relevant to software development
- AOP interesting from theoretical and pratical viewpoint
- AspectJ is an interesting language and tool but not the end of the story

Future work

- (Almost) everything still to be done
- AOP for distributed programming
  - Remote pointcut: extend language, implementation, remote aspect calculus
- Aspect interactions
  - Generalize first results over regular expressions, use of model checking
- Aspects and components
  - Aspects over components with explicit protocols

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