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

AspectJ in one slide

```
pointcut critAcc(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 critAcc(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 critAcc(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

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

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

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 $< 5\%$

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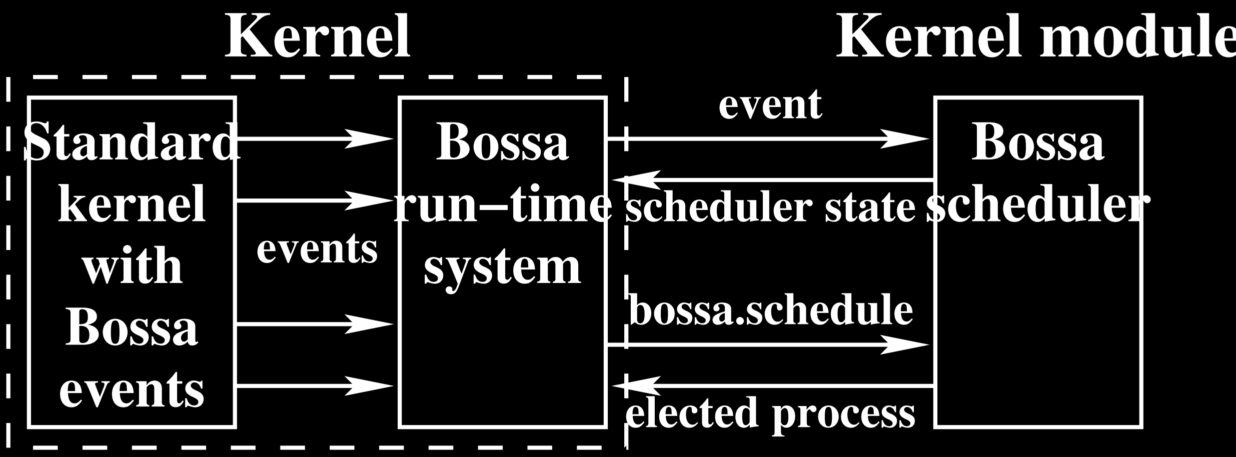
Bossa architecture

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

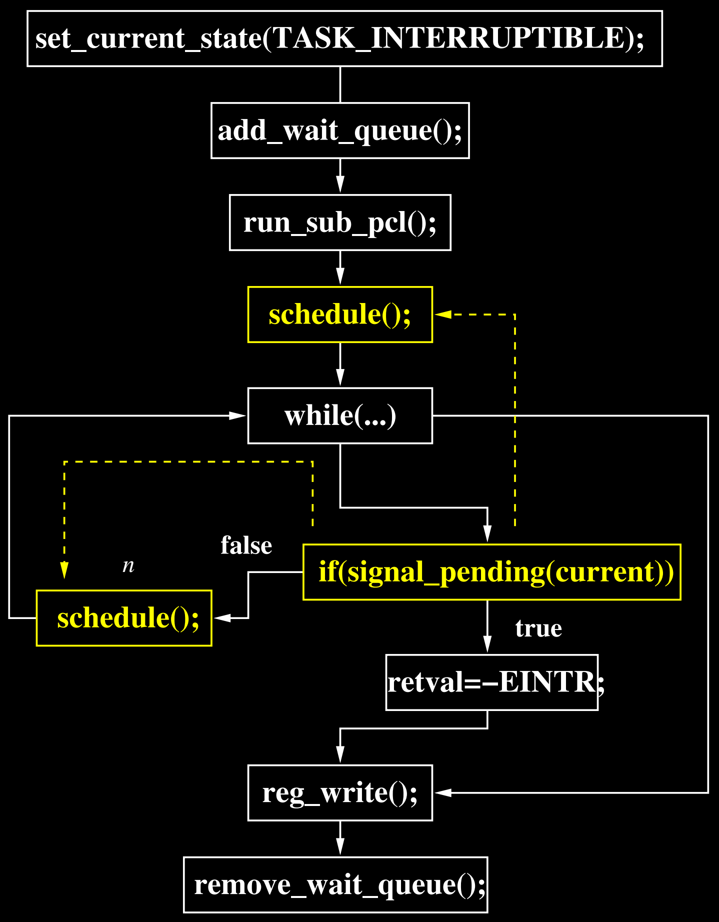


Mediation through events crosscuts the kernel

- 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

$$n : \mathrm{Rewrite}(n, \texttt{schedule\_running})$$

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

"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