dataflow pointcut in aspect-oriented programming

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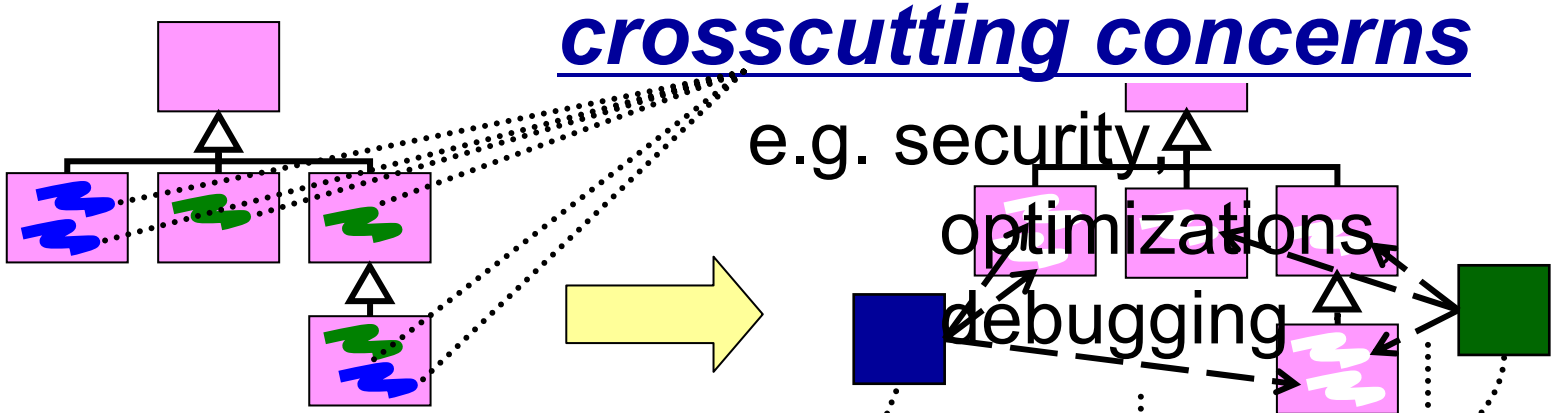
joint work with Kazunori Kawauchi

background: aspect-oriented programming (AOP)

- a paradigm for modularizing ***crosscutting concerns***



- ***aspects***: modules of additional behavior / structure
- ***pointcuts***: specifies "where"

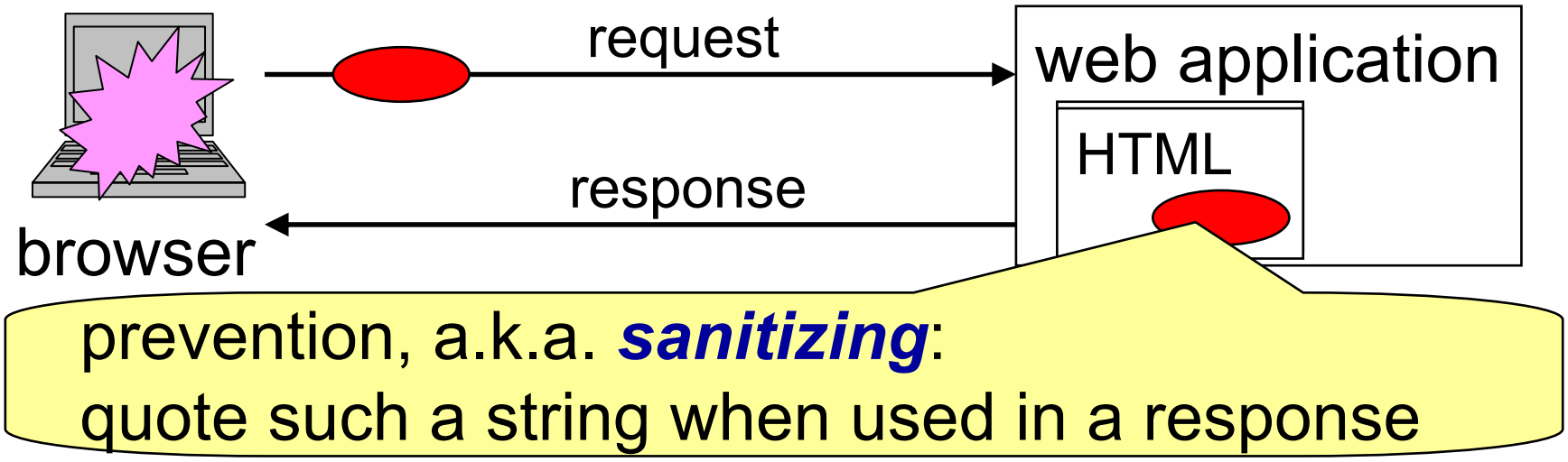
motivation & approach

- existing AOP languages can not straightforwardly support some security concerns
  - key factor: flow of information
- our approach: extend AspectJ [Kiczales+2001] to directly support dataflow
  - by adding a new pointcut

a crosscutting concern: XSS prevention

cross-site scripting (XSS):

- an attack to steal secrets from a browser
- by exploiting a problem in a web app.
  copying request string into response

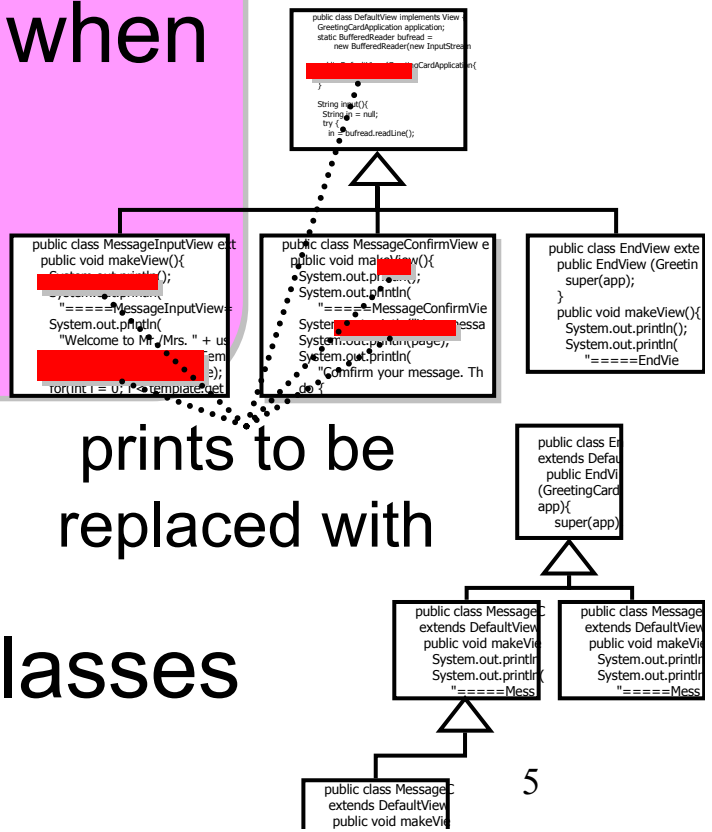


a crosscutting concern: XSS prevention wrt Servlet

sanitizing

replace out.print(s) with out.print(**quote**(s)) when

- generating responses, and
- the arguments come from the browser's request



- sanitizing is crosscutting: web apps. usually generate pages in many classes

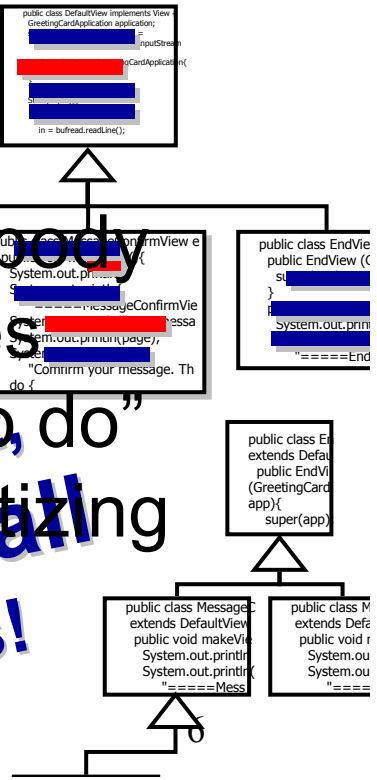
how AspectJ can not implement sanitizing(1)

- a pointcut specifies “where to sanitize”
  i.e., when PrintWriter’s print method is called from a subclass of Servlet
- one module for many classes

```
aspect Sanitizing {
  String around(String s) :
      call(* PrintWriter.print*(String))
      && within(Servlet+) && args(s){
    return proceed(quote(s));
} … }
```

- advice body specifies “what to do” for sanitizing

incorrect, it quotes all strings!



how AspectJ can not implement sanitizing(2)

- a modified aspect would
  - remember all strings got from a request
  - quote only remembered string at printing

```
aspect Sanitizing {
  Set reqStrs = …;
  after() returning (String s) : call(* Request.get(String)) {
      reqStrs.add(s); }
  String around(String s) :
        call(* PrintWriter.print*(String)) && within(Servlet+)
        && args(s) && if(reqStrs.contains(s)) {
      return proceed(quote(s));
} … }
```

how AspectJ can not implement sanitizing(2)

- a modified aspect would
  - remember all strings got from a request
  - quote only remembered string at printing
- ***but not perfect!***
  can not detect
  "derived" strings;
  e.g., concatenated string

```
title =    req.get("title");
name = req.get("name");
attn = title + "  " + name;
…
out.println(attn);
```

not a string in request!

observations on sanitizing & AspectJ

sanitizing

replace out.print(s) with out.print(quote(s)) when
- generating responses, and
- the argument ***comes from*** the browser's request

- requires a pointcut to judge the conditions
  key: ***flow of information***

whereas

- AspectJ pointcut can only reason about
  - instant properties (e.g., meth. name), and
  - flow of control (e.g., cflow)

our proposal: a new dataflow-based pointcut `dflow`

issues:

- design
  - combination with the other pointcuts
  - clear semantics
  - exceptional cases for practical use
    - to exclude some dataflows
    - to handle “native” code
- efficient implementation

sanitizing with `dflow`

sanitizing

replace out.print(s) with out.print(quote(s)) when
- generating responses, and
- the argument comes from the browser's request

```
aspect Sanitizing {
  String around (String s) :
      call(void print(String)) && args(s)
      && dflow[ s, userinput ]
           ( call(String Request.get())
             && returns(userinput) ) {
    proceed(quote(s));
} … }
```

- declarative
- can be combined with the other pointcuts

how `dflow` works (1)

checks how values
are generated
wrt sub-pointcut

```
pect Sanitizing {
 tring around (String s) :
    call(void print(String)) && args(s)
    && dflow[ s, userinput ]
        ( call(String Request.get())
          && returns(userinput) )
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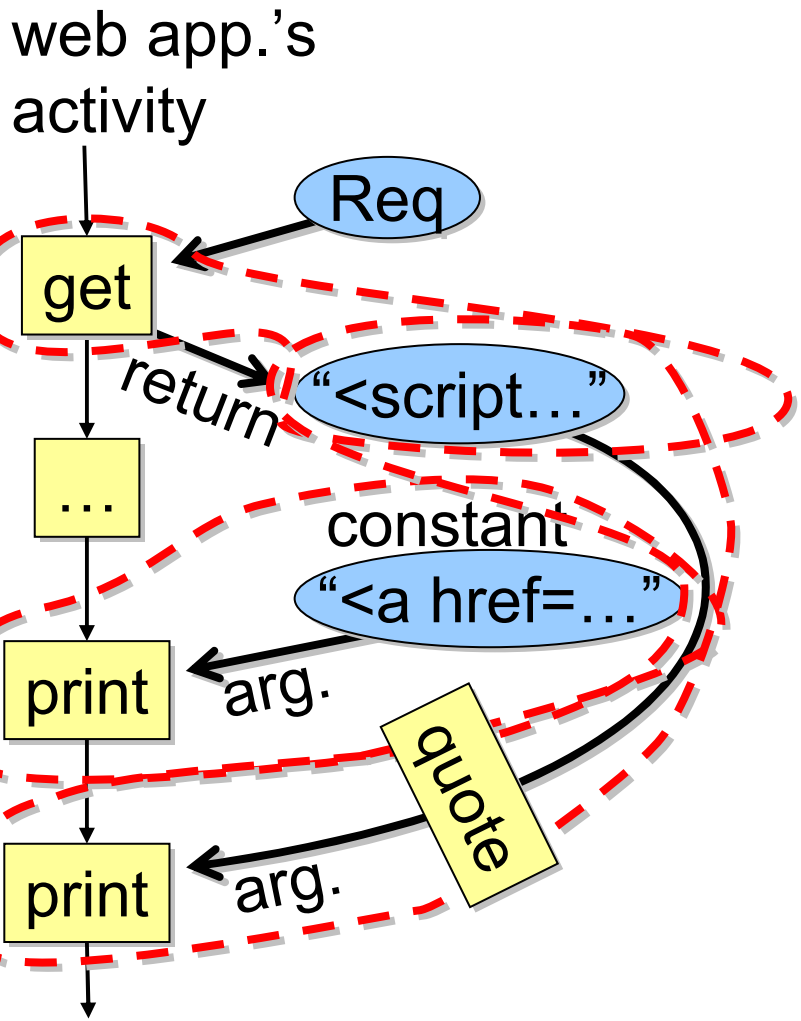
 . }
```



how `dflow` works (2)

it tracks back
- to “indirect” origins
- across modules

```
pect Sanitizing {
 tring around (String s) :
    call(void print(String)) && args(s)
    && dflow[ s, userinput ]
        ( call(String Request.get())
          && returns(userinput) )
proceed(quote(s));
 . }
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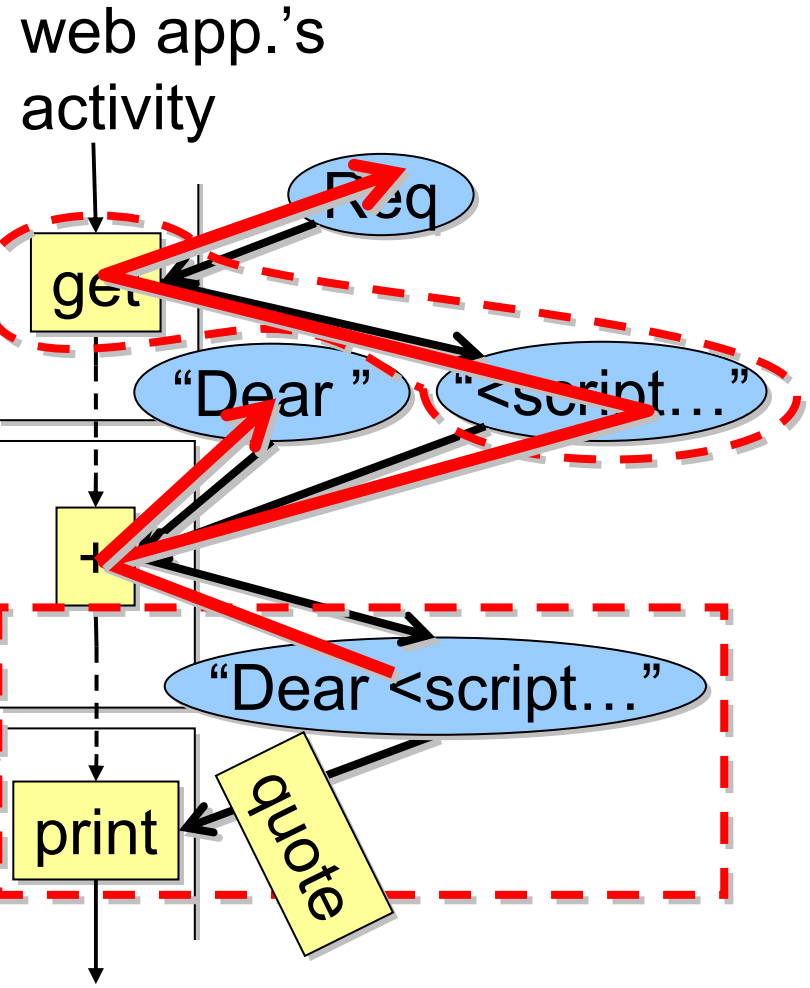
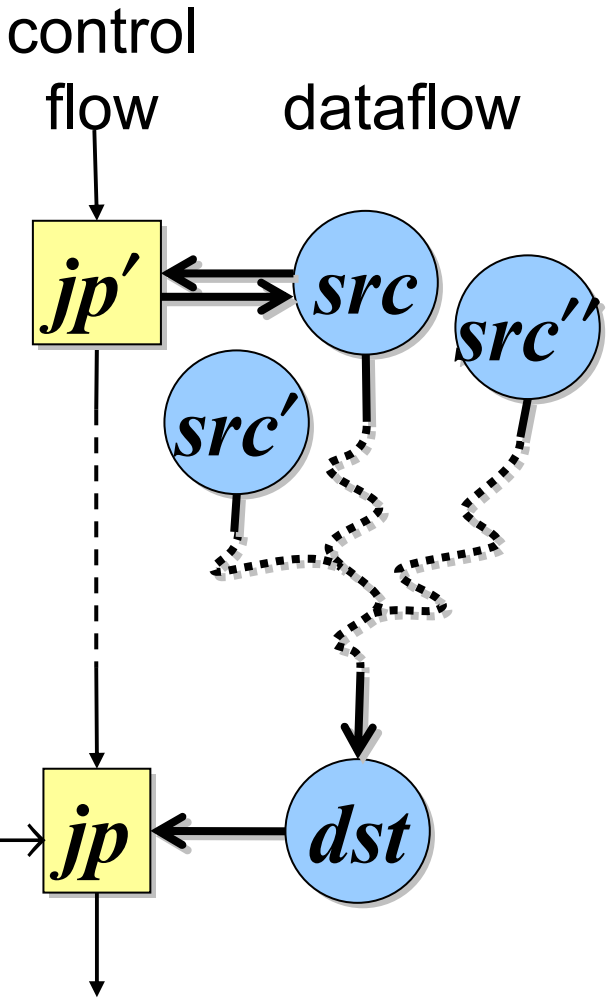


semantics of `dflow`

dflow[*dst*,*src*](*p*) matches *jp*
if ∃*jp′* in the past s.t.

- *jp′* matches *p*
- *p* binds a val. in *jp′* to *src*
- *dst* originates from *src*

* *jp* (join point):
a point in execution

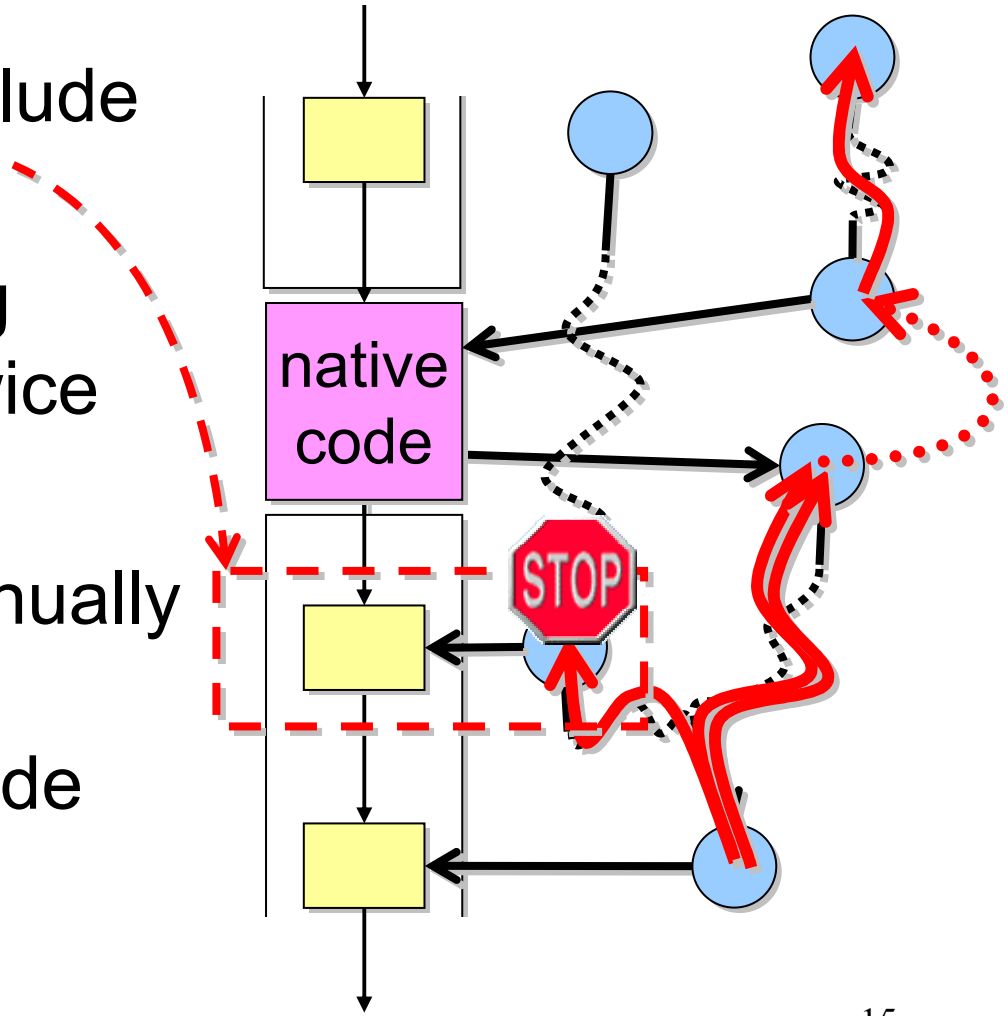


auxiliary constructs

- **`bypassing`** to exclude some dataflow

  e.g., avoid quoting strings twice

- **`propagate`** to manually connect dataflow through “native” code



implementations of dflow

- a proof-of-concept implementation
  - interpretive;
    based on Aspect SandBox interpreter
    [Wand+02,Masuhara+03]
- a practical implementation
  - under development
  - translator to plain AspectJ language

an interpreter-based implementation

- base implementation: AspectJ-like AOP
  - for each dynamic operation (e.g., method call) to be performed,
    - match each jp against pointcuts
    - run advice body when match
- extension for dflow
  - associate a tag to a value
    when the value originates from
    a dflow-specified value

how tags are manipulated

1. gives a tag to dflow (preprocess)
2. tags a value
3. propagates tags
4. checks tags

```
pect S
tring around (String s) :
   call(void print(String)) && args(s)
   && dflow[ s, userinput ]
        ( call(String Request.get())
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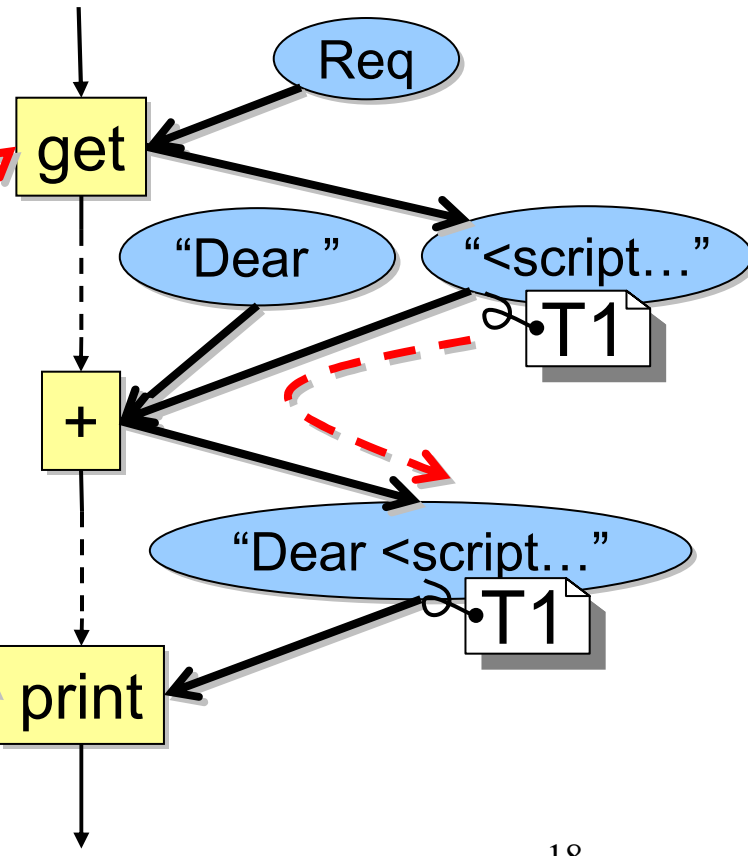
proceed(quote(s));
. }
```



towards translation-based implementation

- basic strategy:

  insert code for tag operations

  into target program

  – most operations can be done by AspectJ

  – finer-grained translation for propagation

- static analysis would eliminate operations for statically-known dataflow

discussion

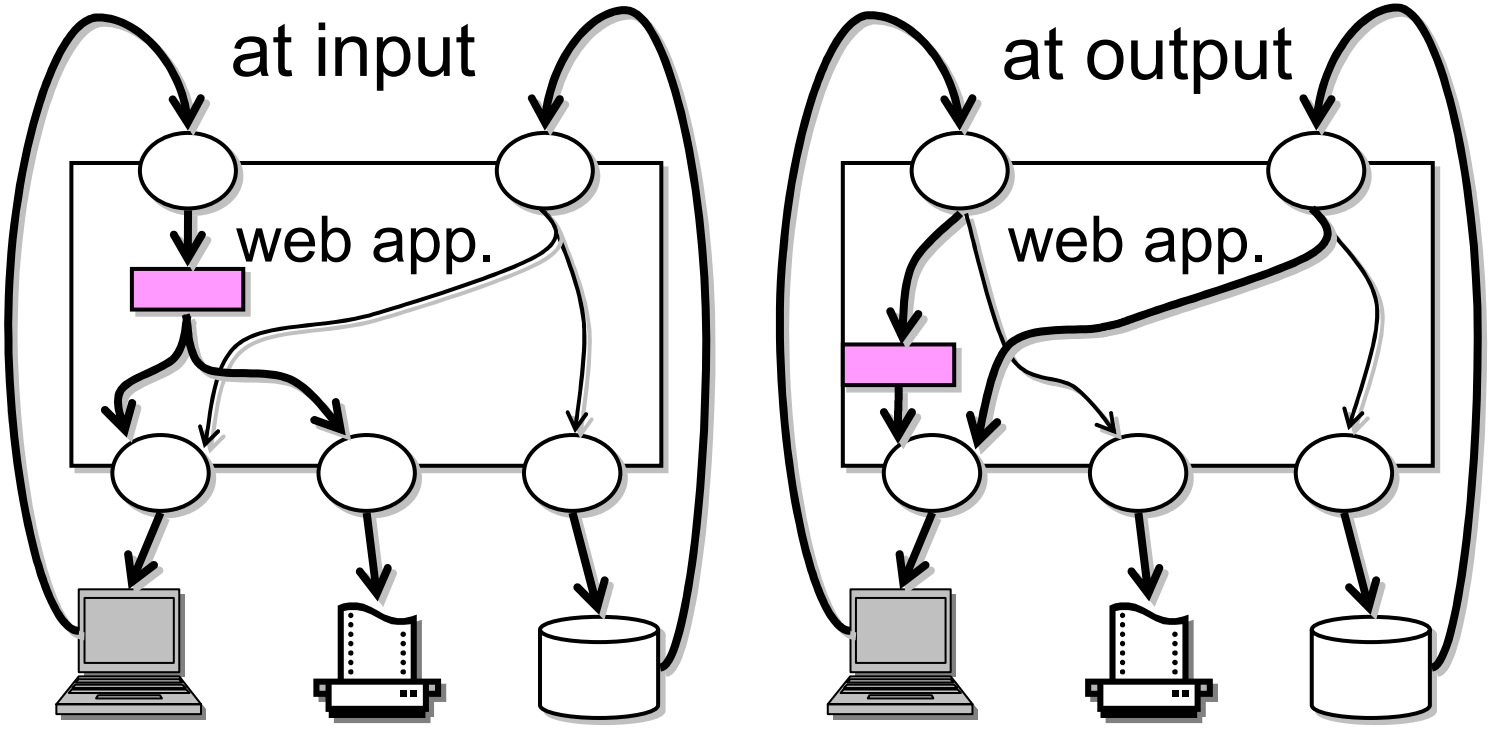
- languages with information-flow analysis [JFlow,SLam,taint-Perl,etc.]
  - more than “dataflow” (cf. implicit flow)
  - not for modularization
- AOP w/ finer-grained jps [Walker+03]
  - could implement dataflow-tracking aspects
  - but less declarative,
    and less opportunity to optimize

conclusion

- **`dflow`**: dataflow-based pointcut
  - useful to declaratively modularize some security concerns
    - would be useful in more general situations
      cf. cflow in AspectJ discriminates polymorphic code by calling context
  - smoothly integrated with existing AOP lang.
  - needs further semantics/implementation work for practical use

why not sanitize when it gets a request?

- because quoting depends on the destination

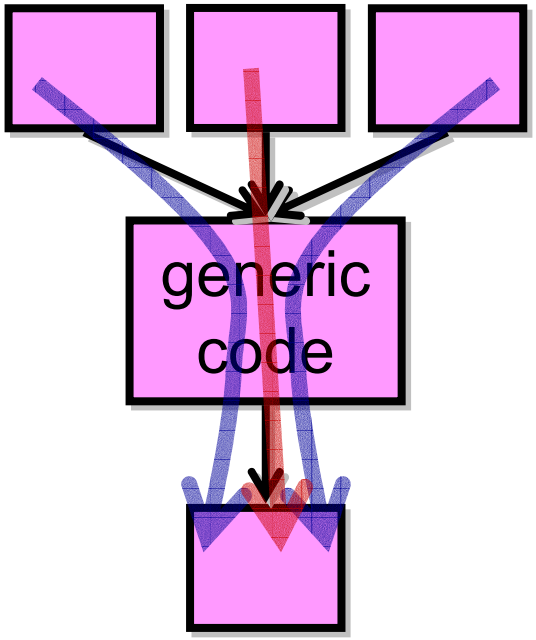


can dflow track dataflow in the database?

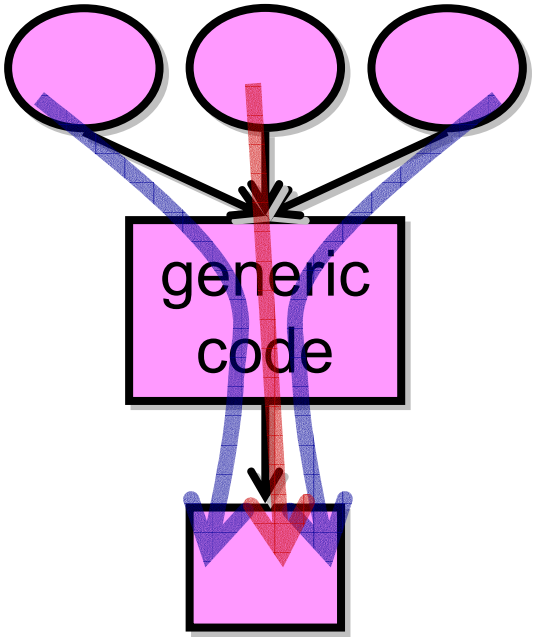
- no,
- but it helps manual tracking by writing an aspect that
  - flags when it writes a record containing a request string
  - regards a flagged record as a request string

is it useful to concerns other than securities?

- cflow specifies execution context



- dflow specifies value context



if web app. concatenates request-string with valid HTML?

- need to modify the pointcut to
  capture such concat. operation
  instead of print operation
- only need to modify the pointcut