Software Language Engineering
Code generation

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Recap

- Grammar -> Parser -> Parse Tree -> AST
- Name resolution: recover referential structure
- Checking: find errors not captured by syntax
- Today:
  - semantics
  - compilation/code generation

Transformation

- Translation
- Restructuring
- Generation
- Optimization
- …

Compilation

- Translation from high-level to low-level
  (= lowering the level of abstraction)
  - Java -> JVM byte code
  - C -> x86 machine code
  - JVM byte code -> x86 machine code
  - QL -> HTML + Javascript
- So not, e.g., Java to C# translation

Compiler pipe line

- Simplification:
  - desugar: unless (x) S -> if (!x) S
  - “lowering”: if (x) S -> if (x) S else ;
- Source level optimization
  - e.g. if (true) S -> S, 0 * x -> 0, etc.
- Intermediate representation
  - example: SSA

Source code generation

- AST based: transform trees, format at the end
- String-based: generate source code directly
  - e.g. using template frameworks

AST based generation

- + type-safe (“syntax correct”)
- + allows post-processing
- - cumbersome, big AST types
- - not WYSIWYG
- - need pretty printer

Template-based generation

- + quick and dirty, no grammar/AST/formatter required
- + wysiwyg
- - not syntax-safe, no IDE support
- - post-processing requires parsing

Byte-code generation

- + no need for target compiler, so fast compilation
- + very expressive
- - low-level: it’s not source code after all
- - requires knowledge of VM infrastructures

Some challenges in code generation

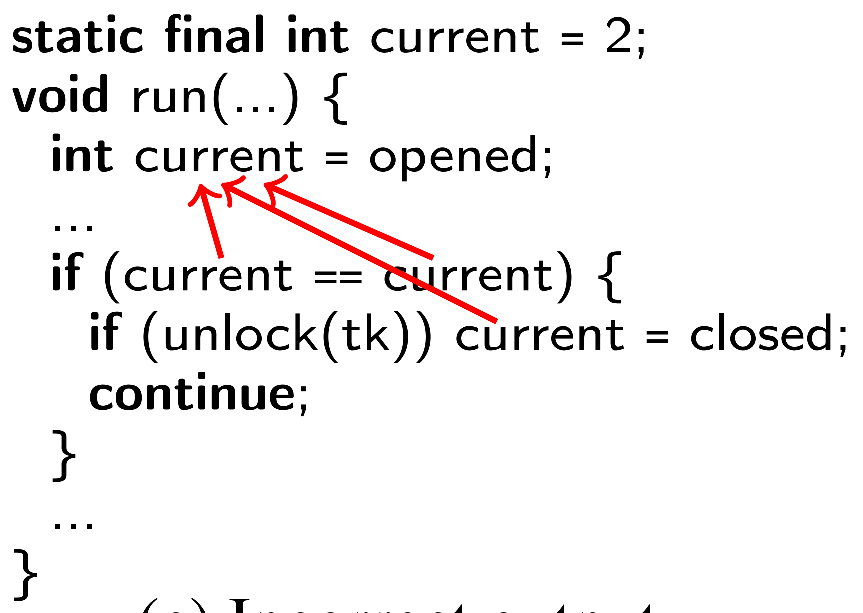
- Origin tracking: how to trace errors and debug info back to original language?
- Modular source code generation is hardly possible.
- Name capture
  - (see, e.g., Erdweg et al., ECOOP'13)

```
state opened
 close => closed
end

state closed
 open => opened
 lock => current
end

state current
 unlock => closed
end
```

(a) Input

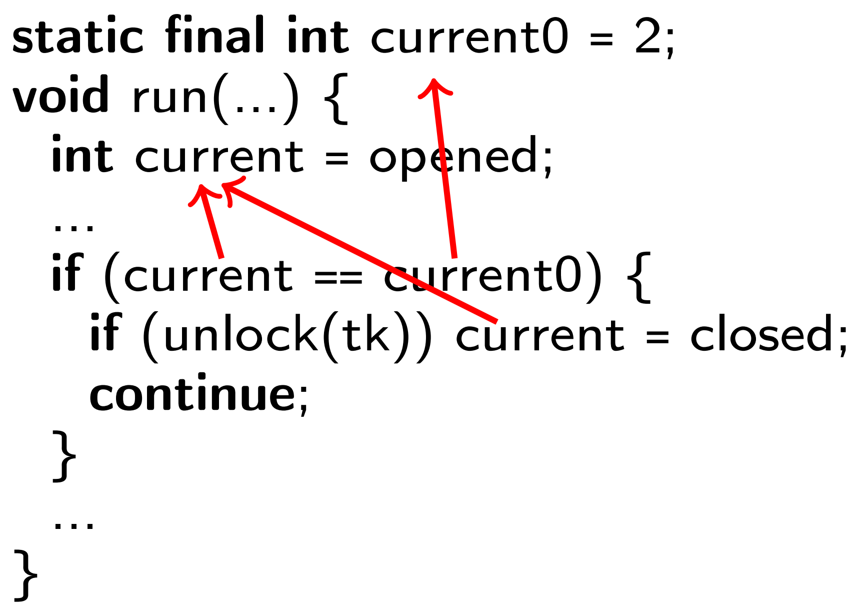
```
str controller2run(Controller ctl) =
  "void run(Scanner input, Writer output) {
   '  int current = <ctl.states[0]>;
   '  while (true) {
   '    String tk = input.nextLine();
   '    <for (s ← ctl.states) {>
   '    <state2if(s)>
   '    <}>
   '  }
   '}";

str state2if(State s) =
  "if (current == <s.name>) {
   '  <for (transition(e, s2) ← s.transitions) {>
   '  if (<e>(tk)) current = <s2>;
   '  <}>
   '  continue;
   '}";
```

(b) Excerpt of state machine compiler



```
static final int current = 2;
void run(...) {
  int current = opened;
  ...
  if (current == current) {
    if (unlock(tk)) current = closed;
    continue;
  }
  ...
}
```

(c) Incorrect output



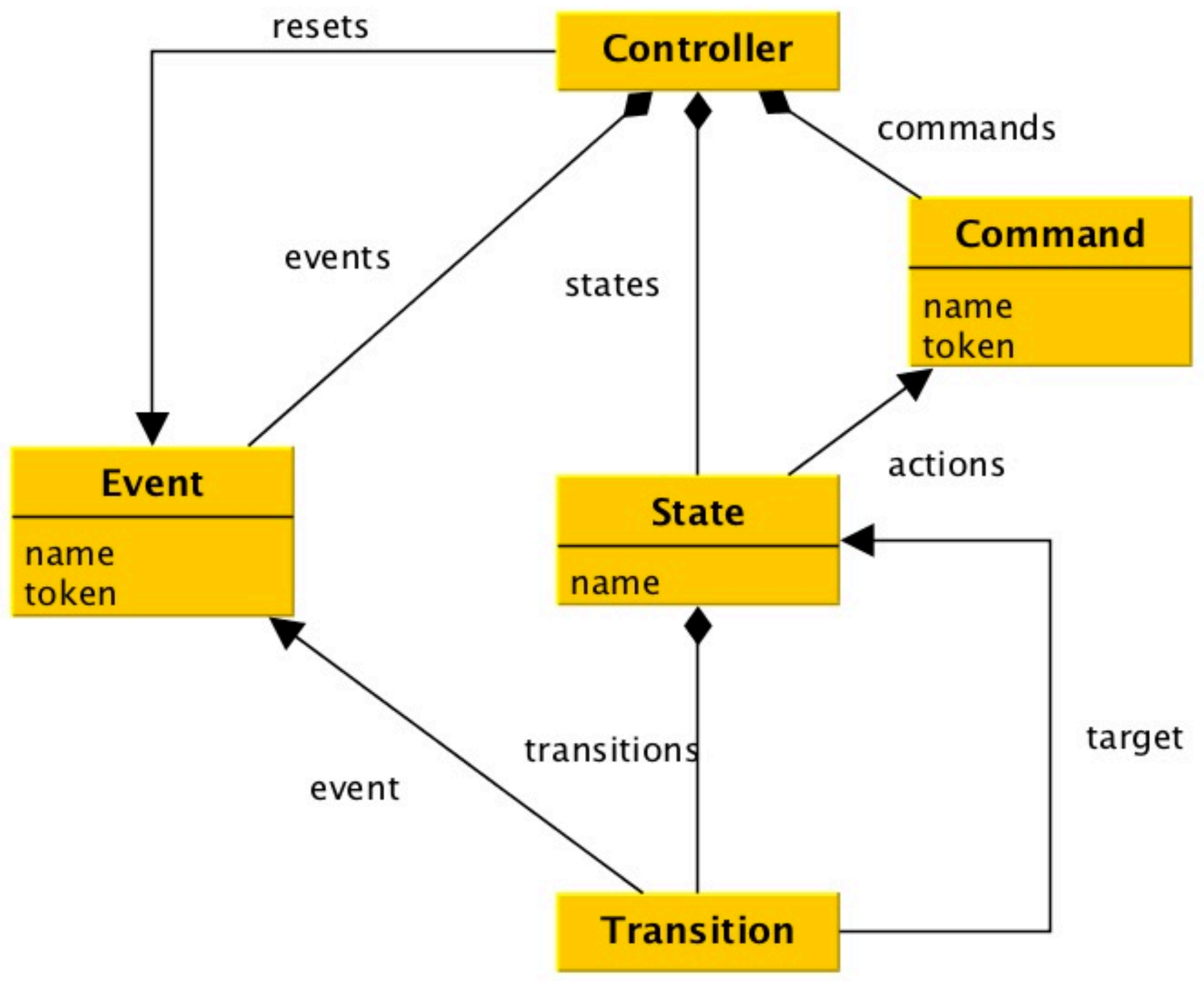
```
static final int current0 = 2;
void run(...) {
  int current = opened;
  ...
  if (current == current0) {
    if (unlock(tk)) current = closed;
    continue;
  }
  ...
}
```

(d) Repaired output

Code generation in Rascal

- Built-in string templates
- AST types for Java, Javascript, HTML, and others
- Flybytes: generate JVM bytcode directly
- Wasm: web assembly (BSc project)

State machines


resets
Controller
commands
Command
name
token
events
states
Event
name
token
State
name
actions
transitions
target
event
Transition