IMPLEMENTING PARSERS AND STATE MACHINES IN JAVA

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ISSUES

- Generated method size in parsers
- Why I need DFA in my parsers
- Implementing DFA in Java
- Predicated DFA edges
- My kingdom for dynamic scoping
- Exceptions for flow-control
- Computed gotos for interpreter instruction dispatch

METHOD SIZE

- Methods generated from big grammar rules can blow past 64k bytes (I'm trying to tighten up the generated code)
- Solution: manually split rules into multiple; not obvious to most users
- Can't do automatically due to actions; issues with args/locals

```
a[int x]
   :  A {...$x...}
   |  B {...$x...}
   ;
```

→

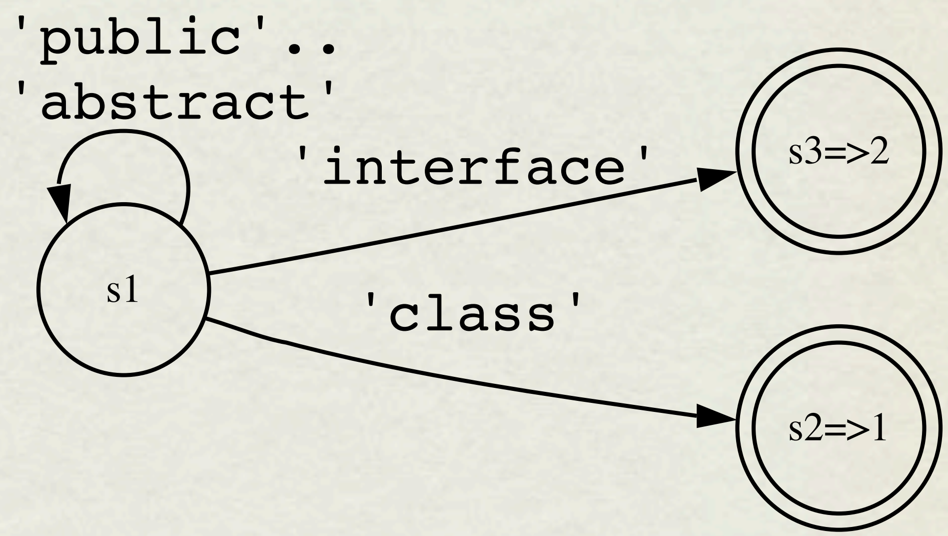
```
a[int x] : a1 | a2 ;
a1 :  A {...$x...} ;
a2 :  B {...$x...} ;
```

Won't compile

LL(*) - MAKING DECISIONS WITH DFA

- Natural extension to LL(k) lookahead DFA: Allows *cyclic* DFA that can skip ahead past the modifiers to class or interface def

```
// LL(*), but non-LL(k) for any k
def : modifier* classDef
    | modifier* interfaceDef
    ;
```



- Don’t approximate entire CFG with a regex; i.e., don’t include class or interface def rules
- Predict and proceed normally with LL parse

SIMULATING STATE MACHINES

- Simulate DFA with bunch of tables

```
public class T {
    static int[][] states
    static int[] s0 = {
        0, 0, 0, 2, 0, 0, 8, 0, 0, 0,
        0, 0, 0, 0, 1, 1, 0, 0, 1, 0,
        ...
    };
    static int[] s1 = { ... };
    ...
    static int[][] states = {s0, s1, ...};
}
```

aside from being slow to initialize, we run into the method size limit

No static arrays in .class: must init elements 1-by-1

```
sipush n
newarray int ; create array

dup          ; dups array
sipush i     ; push index
iconst_0     ; value to store
iastore
```

5 or 6 bytes per element leaves room for only 10k elements for all tables in static ctor

IMPL. DFA WITH GOTO

- To avoid static init issue, encode directly in Java.
- Idea is to use CPU jmp instruction to change state. States are code addresses. Avoids big matrices, vectors.
- “LR parsers can be made to run 6 to 10 times as fast as the best table-interpretive LR parsers.”*
- But, can’t do arbitrary cyclic graphs w/o gotos in Java
- Why not generate bytecodes directly?
  - because of predicated DFA edges; might have to compile arbitrary Java expressions (more in a second...)

* Thomas Pennello, *Very Fast LR Parsing* in Proceedings of the 1986 SIGPLAN symposium on Compiler construction

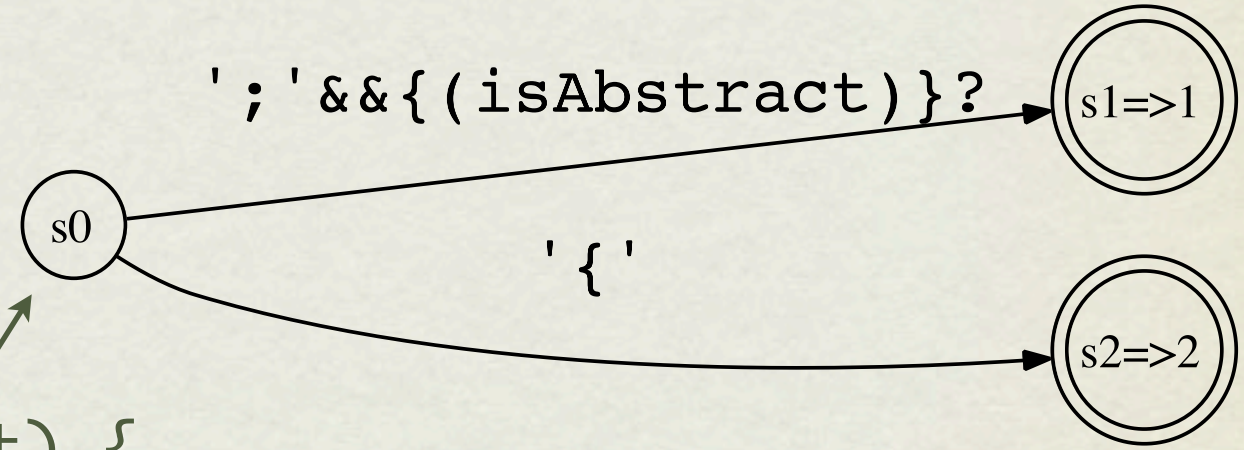
SO, WHAT DO WE DO?

- No gotos => must simulate DFA with arrays
- Encode shorts as chars: 0,9,32 is “\u0000\u0009\u0020”
- Encode arrays as strings, which are stored statically in the constant pool, to avoid static init size limit (got trick from jflex)
- Have to unpack into short/int arrays at runtime to initialize
- Run-length-encode to compress sparse matrices/arrays

PREDICATED DFA

- Edges can be arbitrary expressions; can ref locals and parameters; can't move predicates out of method() to predict()

```
method[boolean isAbstract]
    :   methodHead
        (   {isAbstract}?=> ';'
        |   '{' stat* '}'
        )
    ;
```




```
void method(boolean isAbstract) {
    methodHead();
    int alt = dfa39.predict(input);
    switch (alt) { ... }
}
```

Won't compile in predict()

DYNAMIC SCOPING

- Idea: f() calls g(); g() can see f()'s parameters and locals
- Mostly evil, but solves some code gen issues:
  - let's us automatically split large rule methods
  - let's us move predicates out of context in generated DFA
- Or, I could manage my own parameter stack;
  can't do that for locals, though (defined in arbitrary code)

USING EXCEPTIONS FOR CONTROL FLOW

- Backtracking parser must rewind upon failure and try next alternative
- IF-gates after every rule/token match is slow, big, messy

```
alternative1 ---------------->  // code for an alternative
if (!failed) return;            match(ID); if (failed) return;
rewind input                    match('='); if (failed) return;
alternative2                    expr(); if (failed) return;
...                             ...
```

- But, aren't exceptions very slow? Gafter told me only creating an exception object is slow; throwing is fast. I'm guessing faster than testing `failed` all the time

BYTECODE INSTRUCTION DISPATCH

- Overhead of fetch-decode-execute cycle switch/loop is high
- Poor cache characteristics; perhaps even pipeline issues
- Typical structure:

```
while ( code[ip]!=HALT ) {
  switch ( code[ip] ) {
    case ADD : ... break;
    case JMP : ... break;
    case RET : ... break;
  }
  ip++;
}
```

COMPUTED GO TO

- Threaded interpreter puts dispatch into instruction implementation code; no loop; better cache characteristics

```
codeptr[] impl = { &ADD, &JMP, &RET, ... };

ADD: ... goto impl[code[++ip]];
JMP: ... goto impl[code[++ip]];
RET: ... goto impl[code[++ip]];
```

- Dalvik VM trick: don’t even use address table; allocate *n* bytes per implementation where *n* is power of 2. Instr impl address is
  &firstInstr+code[ip]<<lg*n*.

  E.g., impl.’s at offsets 0, 16, 32, 48, ... for n=16

CONCLUSIONS

- From language implementors point of view, would be nice to have:
  - >64k bytecodes in methods
  - static arrays in .class files
  - gotos for DFA
  - dynamic scoping (splitting rules, predicated DFA edges)
  - computed gotos for interpreters
- I’m not suggesting exposing all this to Java users
- Perhaps secret option Neal Gafter quietly gives out? ;)