Semantic actions for control structures
Statement lists

- So far we have discussed generating code for one assignment statement
- Generating code for multiple statements is easy

\[ stmt\_list \rightarrow stmt \ stmt\_list \mid \lambda \]

- Keep appending (or prepending) the code generated by a single statement to the code generated by the rest of the statement list
- What if statement is not an assignment?
If statements

if <bool_expr_1>
   <stmt_list_1>
else
   <stmt_list_2>
endif
If statements
Generating code for ifs

if <bool_expr_1>
  <stmt_list_1>
else
  <stmt_list_2>
endif

<code for bool_expr_1>
j<!op> ELSE_1
<code for stmt_list_1>
jmp OUT_1
ELSE_1:
<code for stmt_list_2>
OUT_1:
Notes on code generation

- The `<op>` in `j<!op>` is dependent on the type of comparison you are doing in `<bool_expr>`

- When you generate JUMP instructions, you should also generate the appropriate LABELs

  - But you may not put the LABEL into the code immediately

    - e.g., the OUT label (when should you create this? When should you put this in code?)

  - Instead, generate the labels when you first process the if statement (i.e., before you process the children) so that it’s available when necessary

- Remember: labels have to be unique!
Processing Loops
While loops

```
while <bool_expr>
    <stmt_list>
endwhile
```

```
while_stmt
    cond
    block

bool_expr
stmt_list
```
Generating code for while loops

while `<bool_expr>`
    `<stmt_list>`
endwhile;

LOOP:
    `<bool expr>`
    `j<!op> OUT`
    `<stmt_list>`
    jmp LOOP
OUT:

• Re-evaluate expression each time
• Question: what would code for “repeat until” loop look like? For “do while”? 
For loops

for (<init_stmt>; <bool_expr>; <incr_stmt>)
  <stmt_list>
end
Generating code: for loops

```
for (<init_stmt>;<bool_expr>;<incr_stmt>)
  <stmt_list>
end

• Execute init_stmt first
• Jump out of loop if bool_expr is false
• Execute incr_stmt after block, jump back to top of loop
• Question: Why do we have the INCR label?
```
continue and break statements

for (<init_stmt>; <bool_expr>; <incr_stmt>)
  <stmt_list>
end

- Continue statements: skip past rest of block, perform incr_stmt and restart loop
- Break statements: jump out of loop (do not execute incr_stmt)
- Caveats:
  - Code for stmt_list is generated earlier—where do we jump?
  - Keep track of “loop depth” as you descend through AST
Switch statements

switch (<expr>)
    case <const_list>: <stmt_list>
    case <const_list>: <stmt_list>
    ...
    default: <stmt_list>
end
Switch statements

- Generated code should evaluate `<expr>` and make sure that some case matches the result
- Question: how to decide where to jump?

```java
switch (<expr>)
    case <const_list>: <stmt_list>
    case <const_list>: <stmt_list>
    ...  
    default: <stmt_list>
end
```
Deciding where to jump

- Problem: do not know *which label* to jump to until switch expression is evaluated
- Use a jump table: an array indexed by case values, contains address to jump to
  - If table is not full (i.e., some possible values are skipped), can point to a default clause
    - If default clause does not exist, this can point to error code
- Problems
  - If table is sparse, wastes a lot of space
  - If many choices, table will be very large
Jump table example

Consider the code:
((xxxx) is address of code)

Case x is
(0010) When 0: stmts
(0017) When 1: stmts
(0192) When 2: stmts
(0198) When 3 stmts;
(1000) When 5 stmts;
(1050) Else stmts;

Table only has one
Unnecessary row
(for choice 4)

<table>
<thead>
<tr>
<th></th>
<th>jump address</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>JUMP 0010</td>
</tr>
<tr>
<td>1</td>
<td>JUMP 0017</td>
</tr>
<tr>
<td>2</td>
<td>JUMP 0192</td>
</tr>
<tr>
<td>3</td>
<td>JUMP 0198</td>
</tr>
<tr>
<td>4</td>
<td>JUMP 1050</td>
</tr>
<tr>
<td>5</td>
<td>JUMP 1000</td>
</tr>
</tbody>
</table>
### Jump table example

Consider the code:

\[(xxxx) \text{ is address of code}\]

Case \(x\) is

- \(0010\) When 0: stmts0
- \(0017\) When 1: stmts1
- \(0192\) When 2: stmts2
- \(0198\) When 3: stmts3
- \(1000\) When 987: stmts4
- \(1050\) When others: stmts5

Jump table has 6 entries:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>JUMP 0010</td>
</tr>
<tr>
<td>1</td>
<td>JUMP 0017</td>
</tr>
<tr>
<td>2</td>
<td>JUMP 0192</td>
</tr>
<tr>
<td>3</td>
<td>JUMP 0198</td>
</tr>
<tr>
<td>4</td>
<td>JUMP 1050</td>
</tr>
<tr>
<td>...</td>
<td>JUMP 1050</td>
</tr>
<tr>
<td>986</td>
<td>JUMP 1050</td>
</tr>
<tr>
<td>987</td>
<td>JUMP 1000</td>
</tr>
</tbody>
</table>

Table only has 983 unnecessary rows. Doesn’t appear to be the right thing to do! **NOTE: table size is proportional to range of choice clauses, not number of clauses!**
Do a binary search

Consider the code: \((xxxx)\) is address of code)

Case \(x\) is
- \((0010)\) When 0: stmts0
- \((0017)\) When 1: stmts1
- \((0192)\) When 2: stmts2
- \((0198)\) When 3 stmts3
- \((1000)\) When 987 stmts4
- \((1050)\) When others stmts5

Jump table has 6 entries:

<table>
<thead>
<tr>
<th></th>
<th>Jump</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>JUMP 0010</td>
</tr>
<tr>
<td>1</td>
<td>JUMP 0017</td>
</tr>
<tr>
<td>2</td>
<td>JUMP 0192</td>
</tr>
<tr>
<td>3</td>
<td>JUMP 0198</td>
</tr>
<tr>
<td>987</td>
<td>JUMP 1000</td>
</tr>
</tbody>
</table>

Perform a binary search on the table. If the entry is found, then jump to that offset. If the entry isn’t found, jump to others clause. \(O(\log n)\) time, \(n\) is the size of the table, for each jump.
Linear search example

Consider the code:

(xxxx) Is offset of local
Code start from the
Jump instruction

Case x is

(0010) When 0: stmts
(0017) When 1: stmts
(0192) When 2: stmts
(1050) When others stmts;

If there are a small number of choices, then do an in-line linear search. A straightforward way to do this is generate code analogous to an IF THEN ELSE.

If (x == 0) then stmts1;
Elseif (x = 1) then stmts2;
Elseif (x = 2) then stmts3;
Else stmts4;

O(n) time, n is the size of the table, for each jump.
Dealing with jump tables

switch (<expr>)
    case <const_list>: <stmt_list>
    case <const_list>: <stmt_list>
    ...
    default: <stmt_list>
end

<expr>
    <code for jump table>
LABEL0:
    <stmt_list>
LABEL1:
    <stmt_list>
...
DEFAULT:
    <stmt_list>
OUT:

- Generate labels, code, then build jump table
- Put jump table after generated code
- Why do we need the OUT label?
- In case of break statements