Processing control structures

Statement lists

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

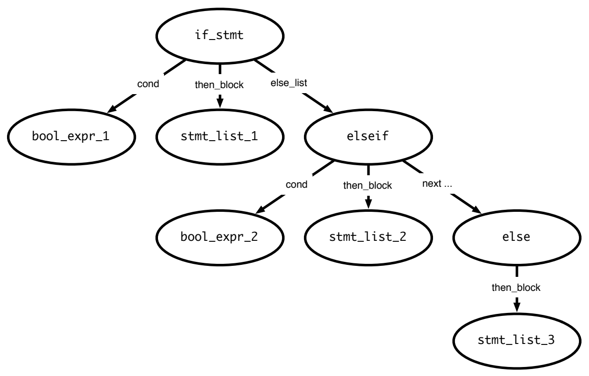
```
stmt_list → stmt stmt_list | λ
```

- 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> then
  <stmt_list_1>
elseif <bool_expr_2> then
  <stmt_list_2>
...
else
  <stmt_list_3>
endif
```

If statements



Generating code for ifs

```
if <bool_expr_1> then
  <stmt_list_1>
elseif <bool_expr_2> then
  <stmt_list_2>
else
  <stmt_list_3>
endif
```

```
  <code for bool_expr_1>
  j<!op> ELSE_1
  <code for stmt_list_1>
  jmp OUT
ELSE_1:
  <code for bool_expr_2>
  j<!op> ELSE
  <code for stmt_list_2>
  jmp OUT
ELSE:
  <code for stmt_list_3>
OUT:
```

Notes on code generation

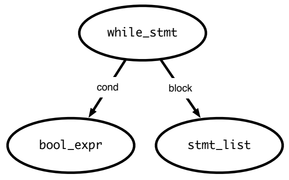
- The <op> in j<!op> is dependent on the type of comparison you are doing in <bool_expr>
- When you generate JUMP instructions, you should also generate the appropriate LABELs
  - But you may not put the LABEL into the code immediately
    - e.g., the OUT label (when should you create this? When should 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!

Create the out label when you process the beginning of an if statement
Put it in code when you are done processing the if statement

Processing Loops

While loops

```
while <bool_expr> do
  <stmt_list>
end
```



Generating code for do-while loops

```
do
  <stmt_list>
while <bool_expr>;
```

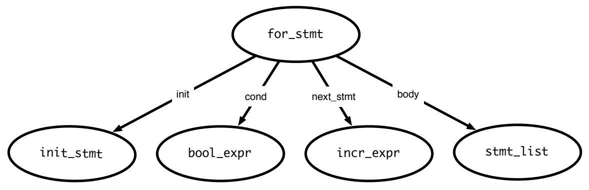
↓

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

- Note that we j<op> instead of j<!op>
  - Jump when the expression is *true*
- Re-evaluate expression each time
- Question: what would code for "repeat until" loop look like?

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
```

↓

```
    <init_stmt>
  LOOP:
    <bool_expr>
    j<!op> OUT
    <stmt_list>
  INCR:
    <incr_stmt>
    jmp LOOP
  OUT:
```

- 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 statements: jump to INCR
break statements: jump to OUT

continue and break statements

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

↓

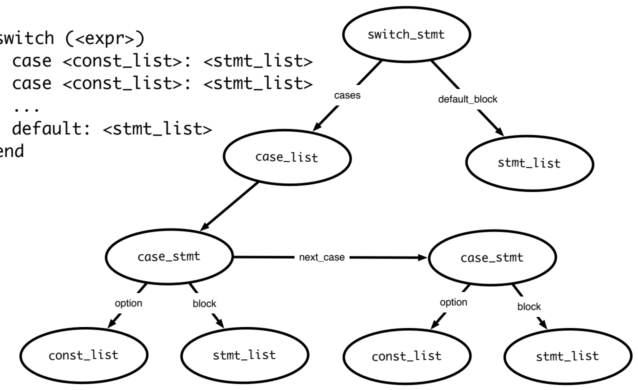
```
    <init_stmt>
  LOOP:
    <bool_expr>
    j<!op> OUT
    <stmt_list>
  INCR:
    <incr_stmt>
    jmp LOOP
  OUT:
```

- 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

continue statements: jump to INCR
break statements: jump to OUT

Switch statements

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



Switch statements

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

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

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)

Jump table has 6 entries:

0	JUMP 0010
1	JUMP 0017
2	JUMP 0192
3	JUMP 0198
4	JUMP 1050
5	JUMP 1000

Jump table example

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

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!***

Jump table has 6 entries:

0	JUMP 0010
1	JUMP 0017
2	JUMP 0192
3	JUMP 0198
4	JUMP 1050
. . .	JUMP 1050
986	JUMP 1050
987	JUMP 1000

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:

0	JUMP 0010
1	JUMP 0017
2	JUMP 0192
3	JUMP 0198
987	JUMP 1000

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