# CS 421 Lecture 12

- Compilation static languages, continued
  - Compiling in context
    - Assignment
    - Break and labeled statements
    - Short-circuit evaluation of boolean expressions
  - Switch statements
  - Arrays
  - Code optimization
- Friday's class: dynamic languages code generation, garbage collection, reflection

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## Notation

- [S] = compiled code for S
- [e] = compiled code for e
- Use subscripts on brackets for additional arguments, e.g.
  [S]<sub>L</sub> is compiled code for S, assuming S occurs within a switch statements labeled L.

## Assignment statements

- Old scheme: [x=e] = let (l,t) = [e] in l; x=t.
- Can give poor results: [x=3] = t=3; x=t

[x=x+1] = t = 1; t2=x+t; x=t2

- Compile expressions in context of target location:
  [e]<sub>x</sub> = code to calculate value of e and store it in x. [e]<sub>x</sub> : instruction list
- ▶ [x=e] = [e]×
- ▶ [n]<sub>x</sub> = "x=n"
- $[y]_x = "x=y"$ , if y a different variable from x;  $\epsilon$ , otherwise
- $[el+e2]_x = let t = new location in <math>[el]_t; [e2]_x; x=t+x$

### break statements

- break statement breaks from one level of switch or while. Cannot translate "break" without knowing context.
- [S]<sub>L</sub> = code for statement S, given that S occurs inside a switch or while statement, and L is the label just after that enclosing statement.

Boolean expressions

 Current scheme: boolean expressions evaluated like any other, placing value in a temporary location:

$$[el < e2] = let (I_1, tI) = [eI], (I_2, t2) = [e2], t = newloc()$$
  
in (I\_1; I\_2; t = tI < t2, t)

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$$[el \&\& e2] = let (I_1, tI) = [eI] (I_2, t2) = [e2] in (I_1; I2; t = tI \&\& t2, t)$$

[if e then SI else S2] = let (I, t) = [e] in (I; CJUMP t LI L2; ...)

• What's wrong?

Boolean expressions w/ short-circuit evaluation

Improved scheme:

[el && e2] = let t = newlocation() $I_1 = [el]_t$  $I_2 = [e2]_t$ Ll, L2 = newlabel() $in (I_1$ CJUMP t, Ll, L2L1: 12L2: , t)

• What's wrong now?

# Compiling boolean expressions in context

- Get better code if boolean expression can jump to correct label as soon as possible
- [e]<sub>Lt,Lf</sub> = code that calculates e and jumps to Lt if it is true,
  Lf if it is false. The code does not save the value anywhere.
- [true]<sub>Lt,Lf</sub>

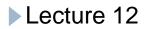
 $[e| < e2]_{Lt,Lf}$ 

# Compiling boolean expressions in context

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## [el && e2]<sub>Lt,Lf</sub>

[while e do S]



Compiling switch statement

Use "jump table" and address calculation

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Compiling object references

#### In expression e.t:

- Type of e is known; call its class C
- Location of field t within C is known; say its offset is o
- [e] will produce (I, t), where t contains pointer to object
- [e.t] = let (l,t) = [e] tl = newlocation() in (l; tl=t+o, tl)
- Method calls e.t(...) more complicated will discuss in a couple of weeks

Compiling array references

Simple rule: If A has elements of type T, and if elements of type T occupy n bytes, then address of A[i] is address of A + i\*n.

• 
$$[A[e]] = let (l, t) = [e]$$
  
in (l  
 $tl = &A$   
 $t2 = t^*w$  (w size of A's elements)  
 $t3 = tl + t2$   
 $t4 = LOADIND t3, t4$ )

Compiling array references

Idea extends to multi-dimensional arrays.

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# Machine-independent optimizations

- Machine-independent optimization = optimizations that can be done at the level of IR – i.e. does not depend upon features of target machine such as registers, pipeline, special instructions
- E.g. "loop-invariant code motion":

int A[100][100]	t1 = &A t2 = i*100
while (j <n) td="" {<=""><td>t2 = i*100 t3 = t2+j</td></n)>	t2 = i*100 t3 = t2+j
x = x + A[i][j]	t4 = t3*4 t5 = t1+t4
}	t6 = LOADIND t5 x = x+t6
	j = j+1

# Machine-dependent optimizations

- Machine-dependent optimization = optimizations that exploit features of target machine such as registers, pipeline, special instructions
  - Register allocation
  - Instruction selection
  - Instruction scheduling