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3AC Translation

Last Time

Intermediate Representations

Intermediate Representations

3AC

What you should know:

- Rational of intermediate representations
- The basic idea of 3AC
  - The instruction set
  - What each instruction more-or-less does

Intermediate Representations

The List of Instruction Templates

Review: Our 3AC Instructions

<opd> := <opd>

<opd> := <opr> <opd>

<opd> := <opd> <opr> <opd>

<lbl>: <INSTR>

goto <lbl>

ifz <opr> goto <lbl>

nop

call <name>

enter <proc>

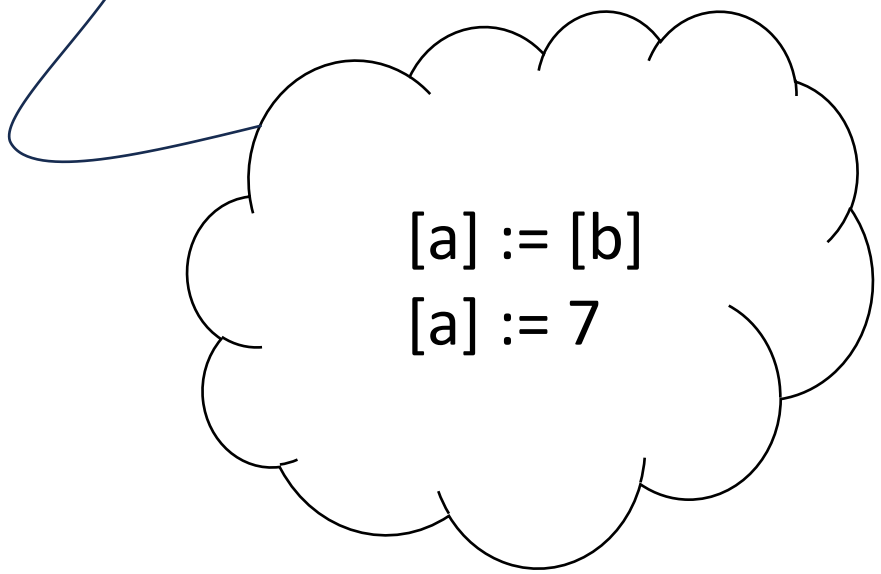
leave <proc>

setarg <int> <opd>

getarg <int> <opd>

setret <opd>

getret <opd>



3AC: Exercise

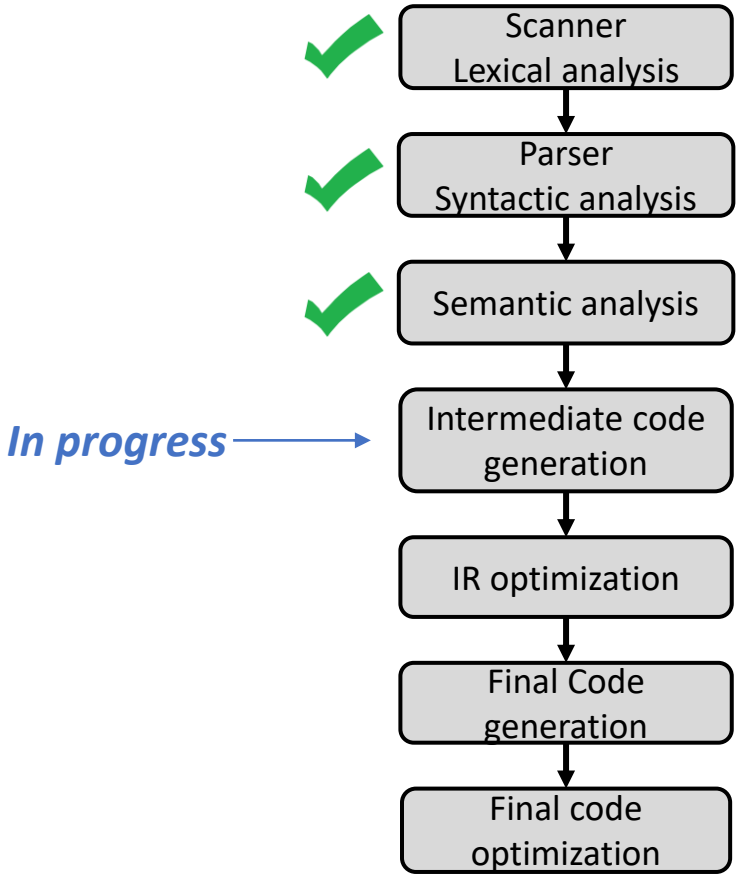
Another Example

```
int x;
int y;
while (x < y) {
    x = x * 2;
}
y = x;
```

```
# tmp1 is an 8 byte local
# x is an 8 byte local
# y is an 8 byte local
LBL1: [tmp1] := [x] LT64 [y]
      if z [tmp1] goto LBL2
      [x] := [x] MULT64 2
      goto LBL1
LBL2: [y] := [x]
```

Compiler Construction

Progress Pics



Done

- We've captured the semantics of the input
- We've checked the program for correctness

Next Steps

- Prepare the program for output

Today's Outline

3AC Translation

The basic idea:

- Traversing the AST

Some example nodes

- Node to quad translations

Implementation details:

- From nodes to Operations/Operands

Intermediate Representations

Flattening the Tree

AST Translation to 3AC

Flattening the Tree

AST Translation to 3AC

Flattening the Tree

AST Translation to 3AC

Consider two major task categories:

What we…

Generate

- (i.e. the 3AC operations for the current node)

Propagate

- (i.e. the 3AC operands used in parent nodes)

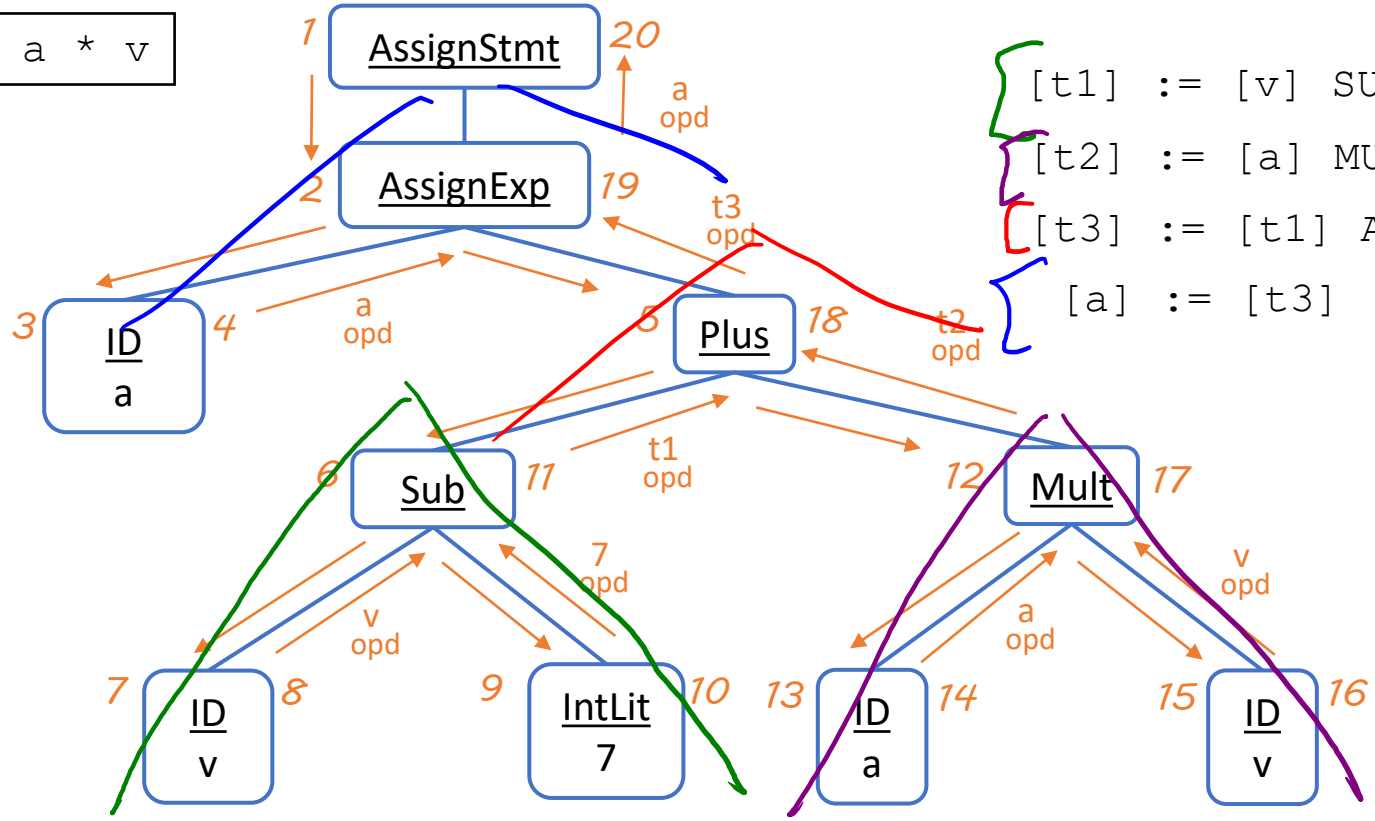
Flattening The Tree: Example

Traversing the AST

Traverse AST, performing two tasks

- Generate 3AC operations
- Propagate 3AC operands

```
a = (v - 7) + a * v
```




```
[t1] := [v] SUB64 7
[t2] := [a] MULT64 [v]
[t3] := [t1] ADD64 [t2]
[a] := [t3]
```

A Brief Aside on Sequencing

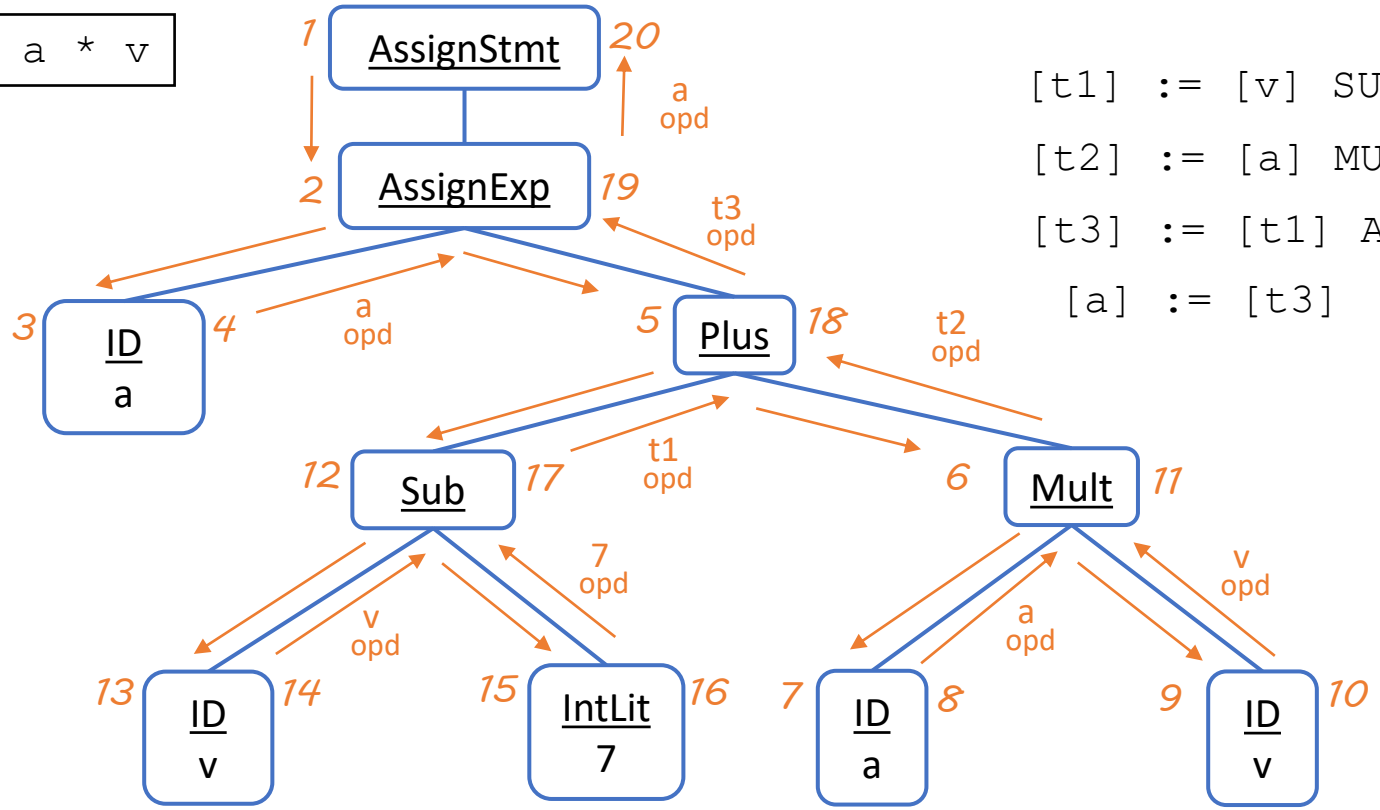
Traversing the AST

What if we walked the tree in a different order?

- Take the RHS of the Plus before the LHS

```
[t2] := [a] MULT64 [v]
[t1] := [v] SUB64 7
[t3] := [t1] ADD64 [t2]
 [a] := [t3]
```

```
a = (v - 7) + a * v
```




```
[t1] := [v] SUB64 7
[t2] := [a] MULT64 [v]
[t3] := [t1] ADD64 [t2]
 [a] := [t3]
```

A Brief Aside on Sequencing

Traversing the AST

What if we walked the tree in a different order?

- Take the RHS of the Plus before the LHS
- C and C++ leave this choice to the compiler!

```
[t2] := [a] * [v]
[t1] := [v] - 7
[t3] := [t1] + [t2]
 [a] := [t3]
```

Participation

Does traversal order matter?

- In this AST?
- For all ASTs?

```
[t1] := [v] - 7
[t2] := [a] * [v]
[t3] := [t1] + [t2]
 [a] := [t3]
```

Example code

```
int foo(){ cout << “hi”; return 0; }
int bar(){ cout << “class”; return 0; }
int main(){
  cout << foo() + bar();
}
```

A Brief Aside on Sequencing

Traversing the AST

What if we walked the tree in a different order?

- Take the RHS of the Plus before the LHS
- C and C++ leave this choice to the compiler!

Order <u>DOES</u> matter

- Can change the program's semantics!

```
int g;

int foo() { return g; }

int bar() { g++; return g; }

int main(){ g = 0; return foo() * bar(); }
```

```
[t2] := [a] * [v]
[t1] := [v] - 7
[t3] := [t1] + [t2]
 [a] := [t3]
```

```
[t1] := [v] - 7
[t2] := [a] * [v]
[t3] := [t1] + [t2]
 [a] := [t3]
```

For our language, always go left to right
(when possible)

Today's Outline

3AC Translation

The basic idea:

- Traversing the AST

Example Nodes:

- Node to quad translations

Implementation details:

- Operations and operators

Intermediate Representations

Example Nodes

Node to Quad Translations

This generate + propagate idea is powerful!

- Basically worked for previous traversals:
  - Name analysis
  - Type analysis
  - Syntax-directed translation
- Let’s see how it works for some various node types

Translating AST Leaves (IDs and Lits)

AST Translation to 3AC

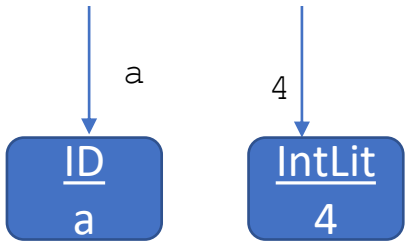
Generate:

- Nothing!

Propagate:

- The value for use in parent

AST Snippet



Translating AssignExp

AST Translation to 3AC

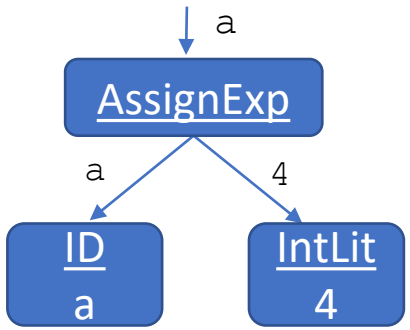
Generate:

- Code for the LHS (recurse)
- Code for the RHS (recurse)
- The actual assignment instruction

Propagate:

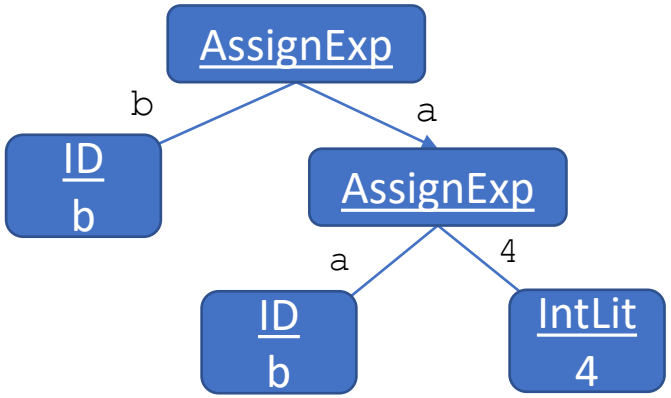
- The LHS of the assignment

```
a = 4
```




```
[a] := 4
```

```
b = (a = 4)
```




```
[a] := 4
[b] := [a]
```

Translating BinaryOp Nodes

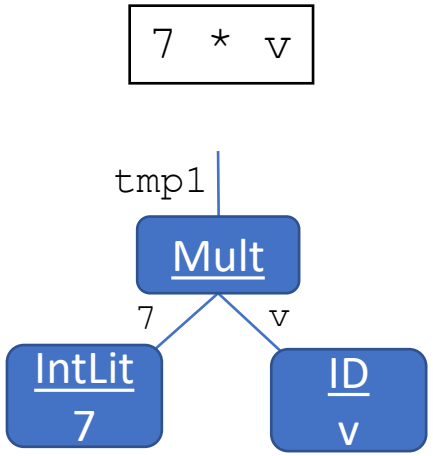
AST Translation to 3AC

Generate:

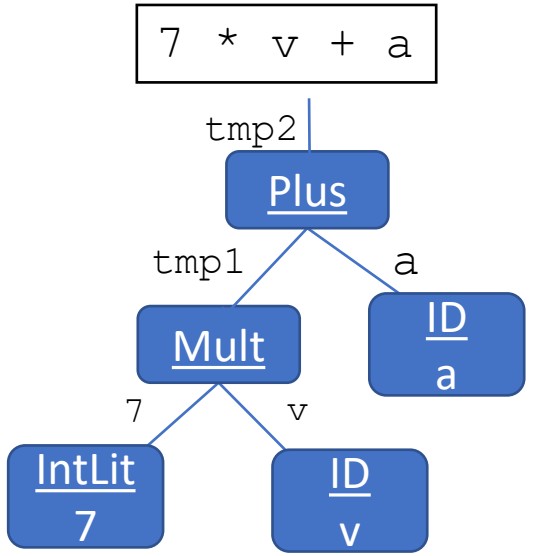
- Code for LHS, RHS (recurse in order)
- Node's operation kind, assigning to new temp

Propagate:

- The new temp value (for use in parent)




```
[tmp1] := 7 MULT64 [v]
```




```
[tmp1] := 7 MULT64 [v]
[tmp2] := [tmp1] ADD64 [a]
```

Translating CallExpNodes

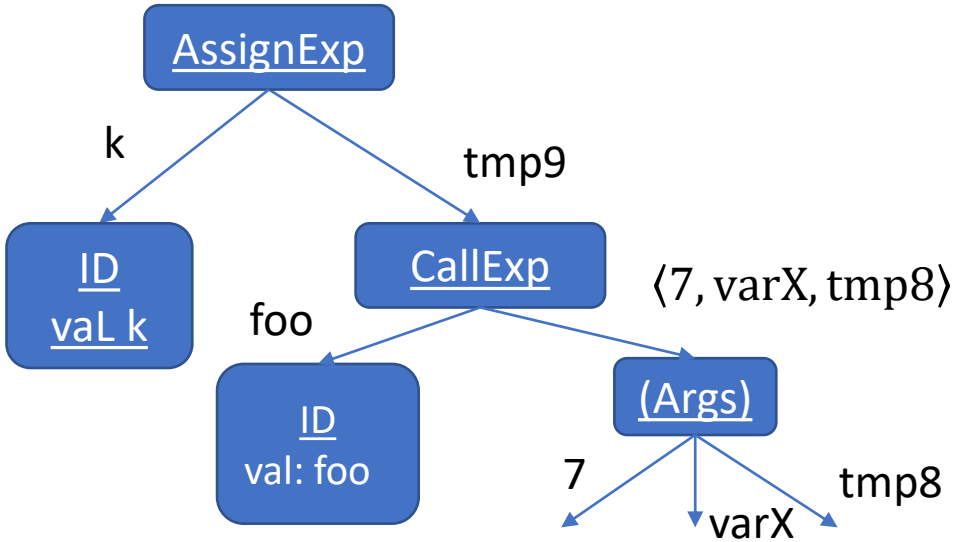
AST Translation to 3AC

Generate:

- (Recurse over args, left to right)
- setarg instrs for each argument
- call instr for function
- getret instr for the result

Propagate:

- The getret symbol



src code snippet

```
k = foo(7,varX,a+b)
```

```
(Arg evaluation)
setarg 1, 7
setarg 2, [varX]
setarg 3, [tmp8]
call fn_foo
getret [tmp9]
[k] := [tmp9]
```

Translating FnDeclNodes

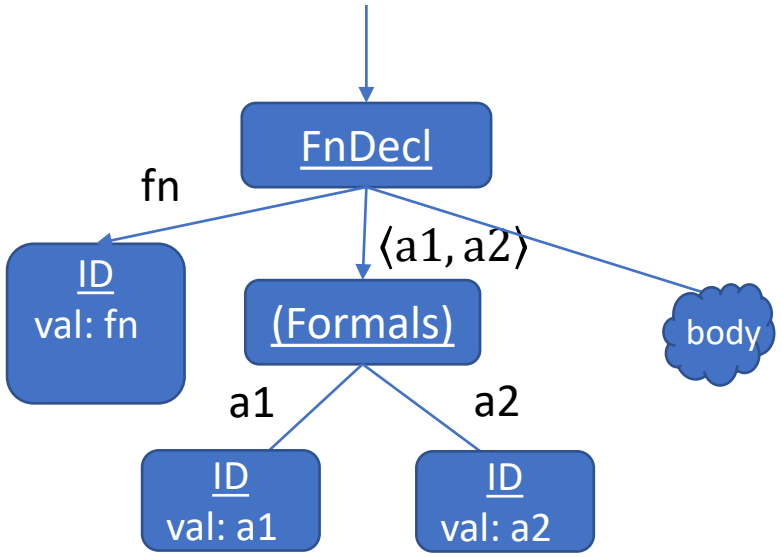
AST Translation to 3AC

Generate:

- `enter` quad to begin scope
- A label for function's end
- `getarg` quads for each argument
- (recurse into body)
- `leave` quad to end scope

Propagate:

- Nothing



src code snippet

```
void fn(int a1, int a2){
  …
}
```

```
enter fn
getarg 1, [a1]
getarg 2, [a2]
(body code)
L_fn_end: leave fn
```

Translating ReturnStmtNodes

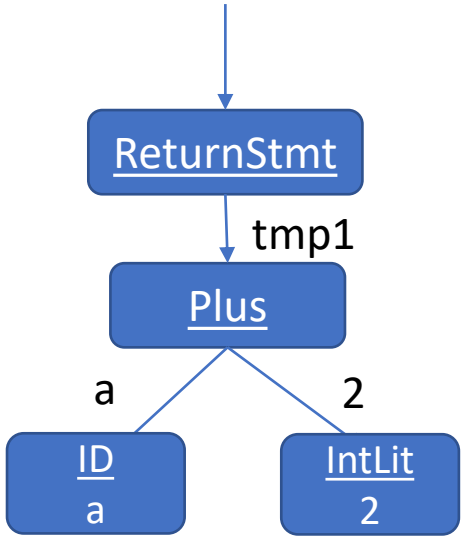
AST Translation to 3AC

Generate:

- (recurse into expression)
- `setret` quad for expression tmp
- goto for the function end

Propagate:

- Nothing



src code snippet

```
return a+2;
```

```
[tmp1] := [a] ADD64 2
setret [tmp1]
goto L_fn_end
```

Translating IfStmtNodes

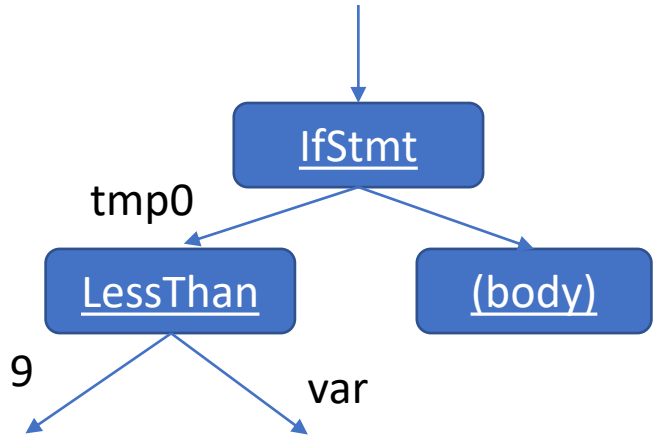
AST Translation to 3AC

Generate:

- (recurse into conditional)
- An “after the body” label
- ifz to after the body label
- (recurse into body)
- nop with the new label

Propagate:

- Nothing




```
[tmp0] := 9 LT64 [var]
ifz [tmp0] goto L_a
(body code)
L_a: nop
```

src code snippet

```
if (9 < var){
   (body code)
}
```

Translating While Loops

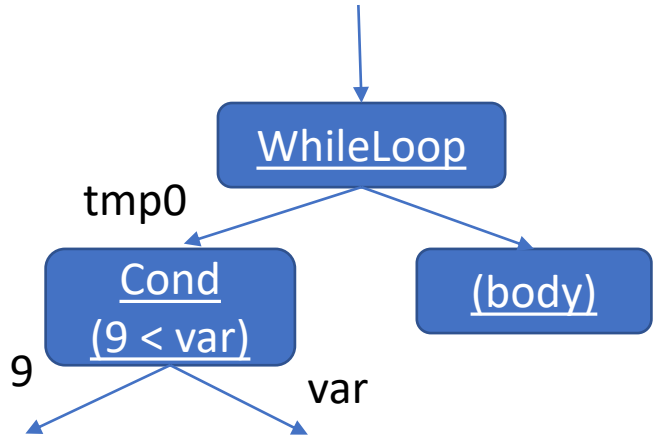
AST Translation to 3AC

Generate:

- Label for loop head
- nop for loop head label
- (recurse into conditional)
- ifz to “after the body”
- (recurse into body)
- Jump back to head

Propagate:

- Nothing




```
L_head: nop
        [tmp0] := 9 LT64 [var]
        ifz[tmp0] goto L_a
        (body code)
        goto L_head
L_a:    nop
```

src code snippet

```
while (9 < var){
   (body code)
}
```

Translating Index

AST Translation to 3AC

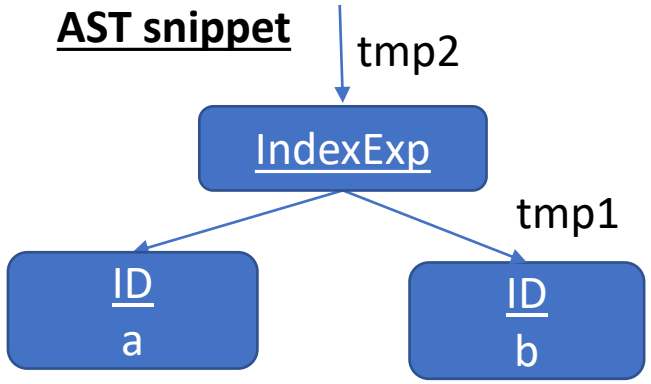
Generate:

- Assign *address* of expression to a new temp

Propagate:

- New temp

AST snippet



src code snippet

```
record R{
   int a;
}
…
R r;
r.a = 1;
```

3AC snippet

```
[tmp1] := [b]
 tmp2  := r @ a
```

Today's Outline

3AC Translation

The basic idea:

- Traversing the AST

Example Nodes:

- Node to quad translations

Implementation details:

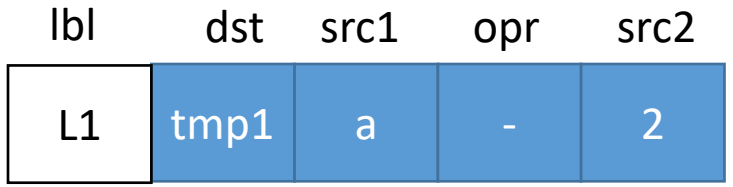
- Operations and operators

Intermediate Representations

3AC Data Structures

AST Translation to 3AC: Implementation

- One class per 3AC node type
  - Often referred to as “Quads” – has at most 4 fields (+ label)
  - Each procedure maintains a list of its quads



L1: [tmp1] := [a] SUBGT 2

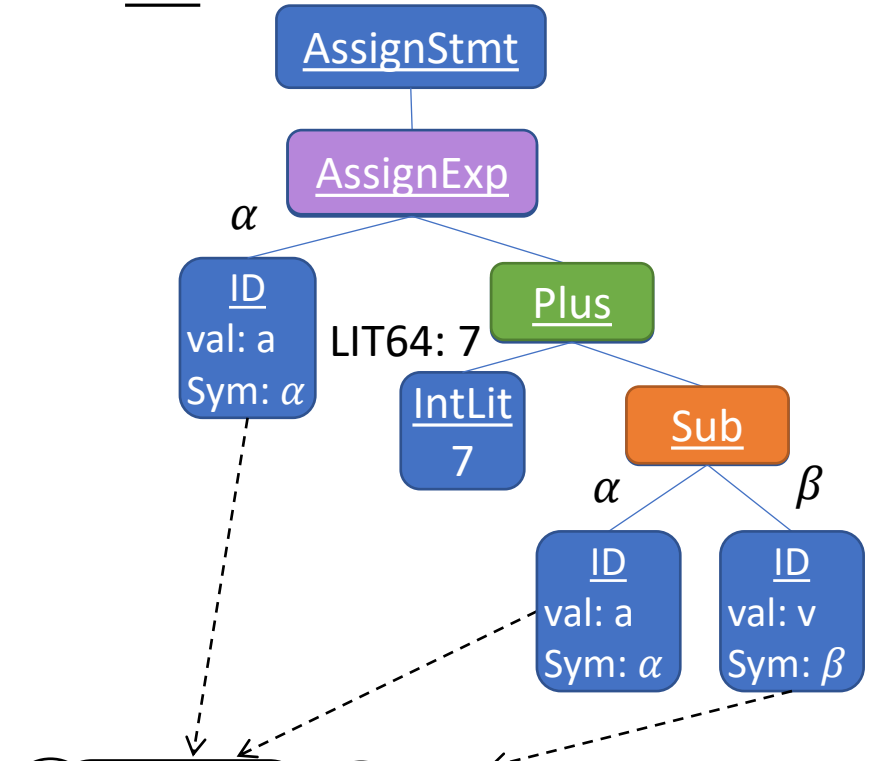
Translation Implementation

AST Translation to 3AC

src code snippet

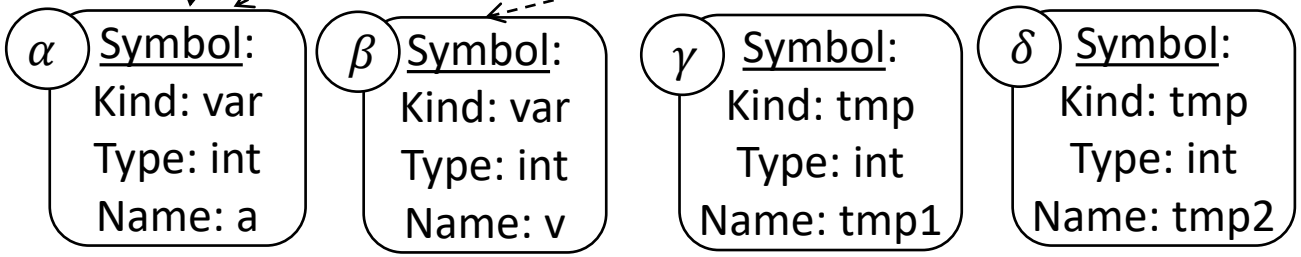
```
a = 7 + (a - v)
```

AST



Quads

lbl	dst	src_1	opr	src_2
	tmp1 (γ)	a (α)	SUB 64	v (β)
	tmp2 (δ)	7	ADD 64	tmp1 (γ)
	a (α)	tmp2 (δ)	ASG 64	



Translation Implementation

AST Translation to 3AC

At this point, we can discard the AST

- New data structures for the 3AC representation:
  - Quad class (with subclasses for each quad type)
  - Procedure class
    - Contains list of quads
  - Operand abstraction (symbols)

Quads

lbl	dst	src_1	opr	src_2
	tmp1 (γ)	a (α)	SUB 64	v (β)
	tmp2 (δ)	7	ADD 64	tmp1 (γ)
	a (α)	tmp2 (δ)	ASG 64	

Lecture End

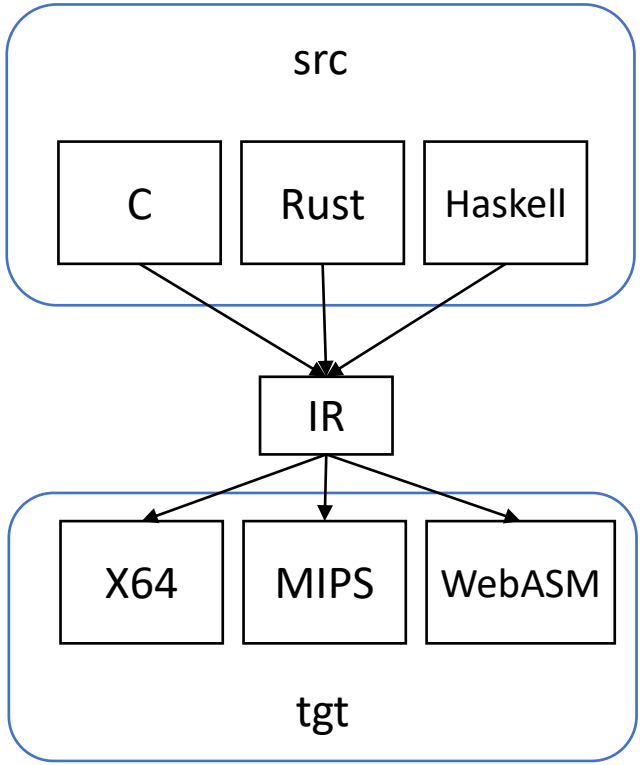
3AC Translation

We've successfully flattened the AST

- Got a nice target for final code generation
- Removed the nesting
- Make execution order explicit

Next time

- Start exploring the compiler targets



The multicompiler concept
One IR for many sources, many targets

3AC in Summary

AST Translation to 3AC

A Nice Linear IR

- Gets us close to real hardware
- Abstract enough to be used in a variety of backends