Intermediate Representation Construction in a Nutshell

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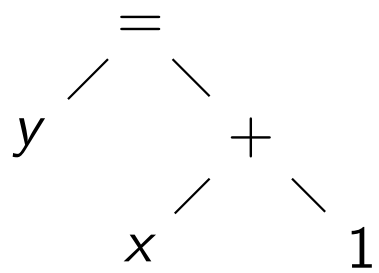
Code Generation for Expresssions



- Do *not* evaluate expression
- *Create code*, which, *when run*, evaluates the expression
- IR construction is code generation, just for a virtual machine
- *Recursively* create code for expressions
- Create code for operands, then create code for current node
- Same order as evaluating, but generating code instead

Code Generation for a Constant

1

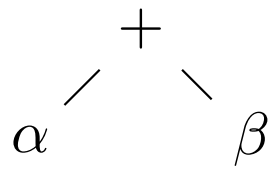
```
Constant::makeRValue() {
  return createConstantNode(value);
}
```

Different Code Generation in Different Contexts

```
expr = ...    /* L-value */
...  = expr   /* R-value */
if (expr)     /* Control flow */
```

- Code generated depends on context, where the expression appears
- L-value: *address* of the object denoted by an expression
- R-value: *value* of an expression
- Control Flow: Branch depending on result of an expression
- Different contexts call each other recursively for operands

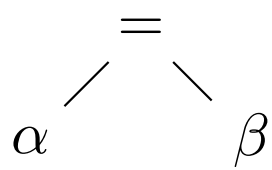
Code Generation for $+$



- Generate code for operands
- Then generate code for $+$

```
Addition::makeRValue() {
  l = left->makeRValue();
  r = right->makeRValue();
  return createAddNode(l, r);
}
```

Code Generation for $=$



- L-value: *address* of the object denoted by an expression
- R-value: *value* of an expression
- L and R stand for left and right hand side (of assignment)
- Assignment happens as *side effect* of the expression

```
Assignment::makeRValue() {
  address = left->makeLValue();
  value   = right->makeRValue();
  createStoreNode(address, value);
  return value;
}
```

Code Generation for $*$ (Indirection)

- R-value of $*\alpha$ is the value loaded from the address denoted by the R-value of α
- Address of the object denoted by $*\alpha$ is the value of α: L-value of $*\alpha$ is the R-value of α

```
Indirection::makeRValue() {
  address = operand->makeRValue();
  return createLoadNode(address);
}

Indirection::makeLValue() {
  return operand->makeRValue();
}
```

Code Generation for & (Address)

- Value of &α is the address of the object denoted by α: R-value of &α is the L-value of α
- &α does not denote an object: &α is not an L-value

```
Address::makeRValue() {
  return operand->makeLValue();
}

Address::makeLValue() {
  PANIC("invalid L-value");
}
```

Connection between L-value and R-value

- R-value is just loading from L-value
- Unfortunately most expressions are not an L-value, i.e. do not denote an object

```
virtual Value* Expression::makeRValue() {
  address = makeLValue();
  return createLoadNode(address);
}

virtual Value* Expression::makeLValue() {
  PANIC("invalid L-value");
}
```

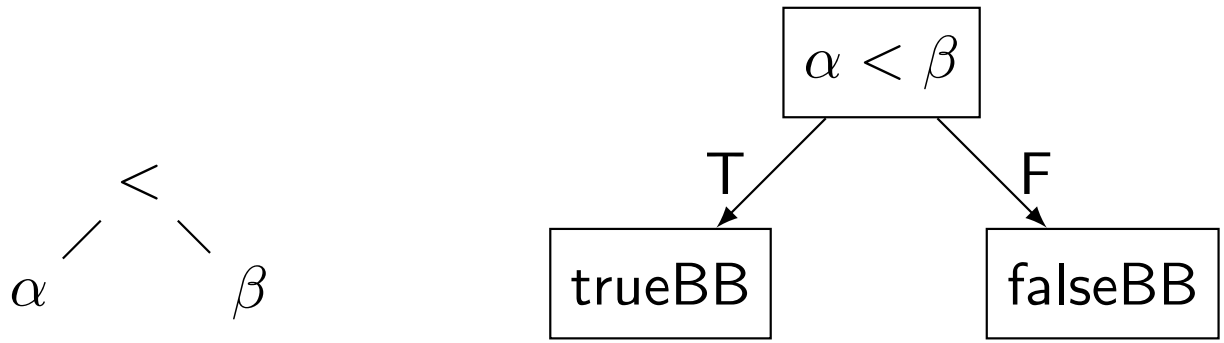
Control-Flow Code Generation for Condition

```
if (C) S1 else S2
```

- If C evaluates to $\neq 0$ continue at S1
- Otherwise continue at S2
- Label/Basic block of S1 and S2 are input for code generation

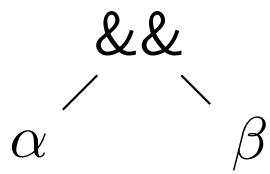
```
virtual void Expression::makeCF(trueBB, falseBB);
```

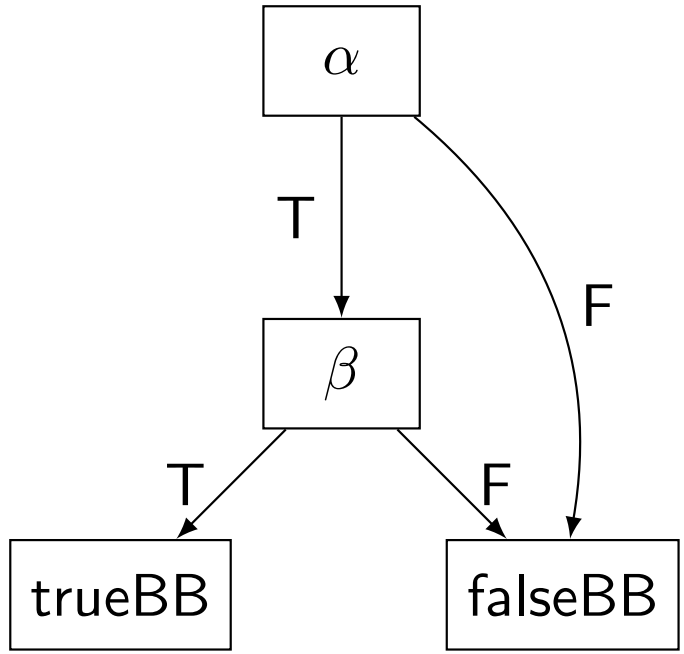
Control-Flow Code generation for $<$




```
LessThan::makeCF(trueBB, falseBB) {
  l    = left->makeRValue();
  r    = right->makeRValue();
  cond = createCmpLessThanNode(l, r);
  createBranch(trueBB, falseBB, cond);
}
```

Control-Flow Code generation for &&

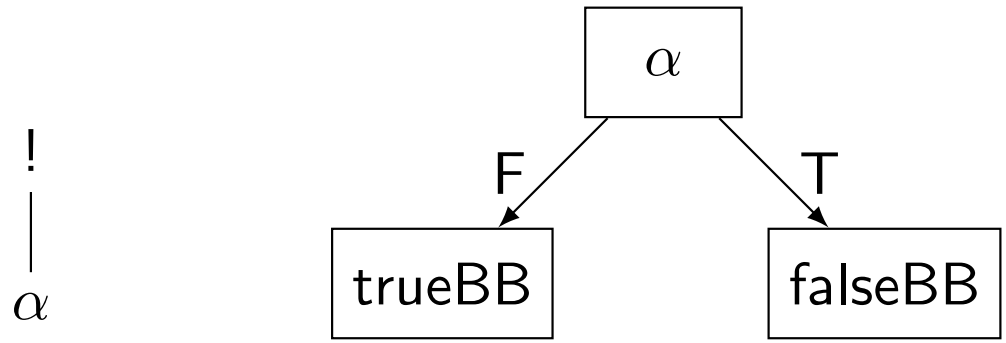




- Lazy evaluation is part of semantics: β might have side effects
- Stop evaluation if value of left hand side determines result

```
LogicalAnd::makeCF(trueBB, falseBB) {
  extraBB = createBasicBlock();
  left->makeCF(extraBB, falseBB);
  setCurrentBB(extraBB);
  right->makeCF(trueBB, falseBB);
}
```

Control-Flow Code Generation for !

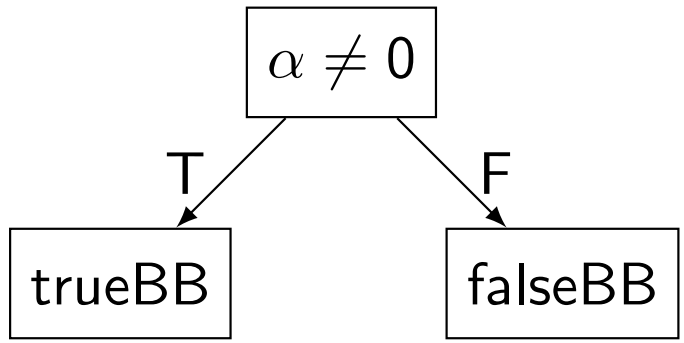


- To negate the condition, just swap the targets

```
LogicalNegation::makeCF(trueBB, falseBB) {
  operand->makeCF(falseBB, trueBB);
}
```

Control-Flow Code Generation for Arbitrary Expression

α

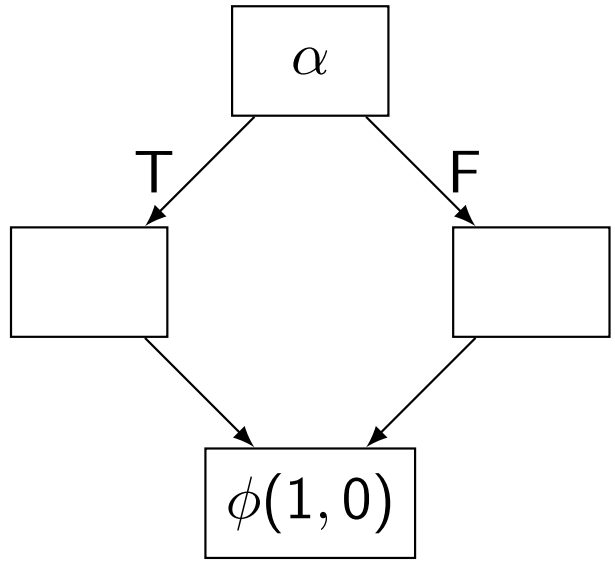


- Test R-value $\neq 0$

```
virtual Expression::makeCF(trueBB, falseBB) {
  PANIC("implement this");
}
```

R-value Code Generation for Control Flow Expression

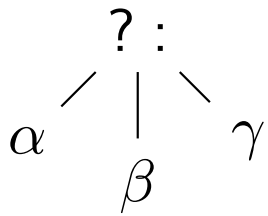
α

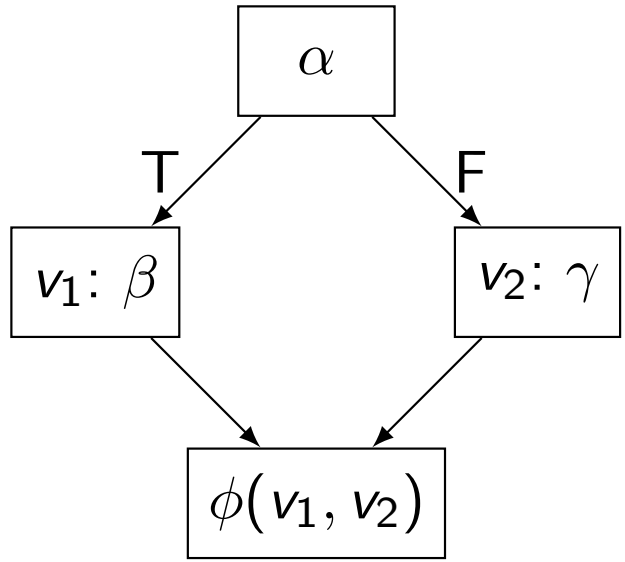


- Control flow operators produce 1 and 0
- Select the value depending on whether the true or false basic block was reached

```
ControlFlowExpression::makeRValue() {
  PANIC("implement this");
}
```

R-value Code Generation for Conditional Expression

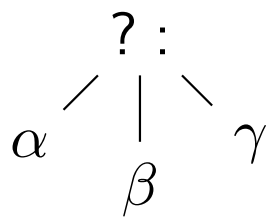


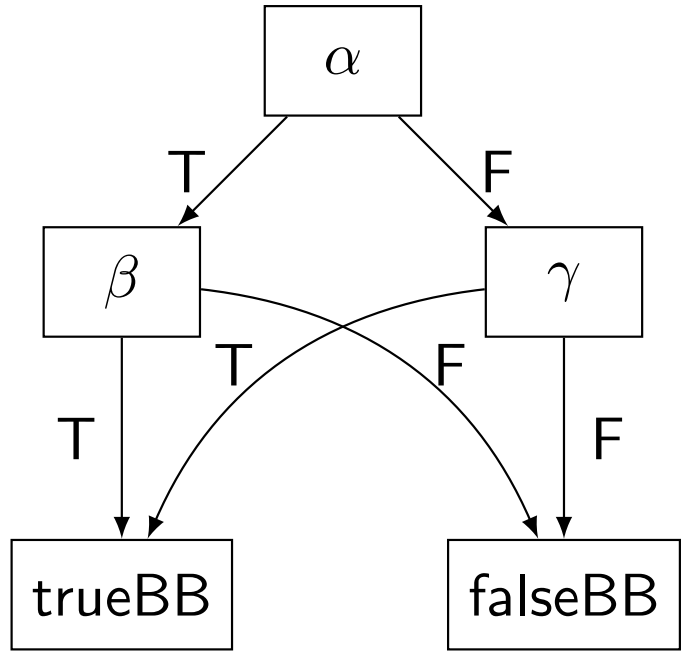


- First evaluate condition α to control flow
- Then either evaluate consequence β or alternative γ
- Pick result using a ϕ

```
ConditionalExpression::makeRValue() {
  PANIC("implement this");
}
```

Control-Flow Code Generation for Conditional Expression





- First evaluate condition α to control flow
- Then either evaluate consequence β or alternative γ to control flow

```
ConditionalExpression::makeCF(trueBB, falseBB) {
  PANIC("implement this");
}
```