Compilation (#5) : Syntax-Directed Code Generation

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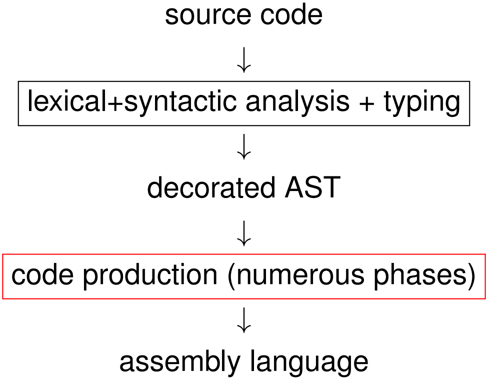
Big picture



source code

↓

lexical+syntactic analysis + typing

↓

decorated AST

↓

code production (numerous phases)

↓

assembly language

Rules of the Game here

For this code generation:

- Still no functions and no non-basic types. (mini-while)
- Syntax-directed: one grammar rule → a set of instructions.
  - Code redundancy.
- No register reuse: everything will be stored on the stack.

The Target Machine : RISCV (course #1)

1. 3-address syntax-directed Code Generation
   - Rules
2. Memory allocation
3. LAB: Direct Code Generation
4. Conclusion

A first example (1/2)

How do we translate:

```
int x, y;
x=4;
y=12+x;
```

- Variable decl's visitor gives a place to each variable: $x \mapsto place0$, $y \mapsto place1$.
- Compute 4, store somewhere, then copy in x's place.
- Compute $12 + x$: 12 in `place2`, copy the value of x in `place3`, then add, store in `place4`, then copy into $y's$ place.

▶ the code generator will use a place generator called `new_tmp()`

A first example: 3@code (2/2)

“Compute 4 and store in x (temp0)”:

```
li temp2, 4
mv temp0, temp2
```

Objective

3-address RISCV **Code Generation** for the Mini-While language:

- All variables are int/bool.
- All variables are global.
- No functions

with syntax-directed translation. Implementation in Lab (MiniC)

- ▶ This is called **three-adress code generation**

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Code generation utility functions

We will use:

- A new (fresh) temporary can be created with a `newtemp()` function.
- A new fresh label can be created with a `new_label()` function.
- The generated instructions are close to the RISCV ones.

Abstract Syntax

Expressions:

$$
\begin{array}{rcll}
e & ::= & c & \text{constant} \\
  & \mid & x & \text{variable} \\
  & \mid & e + e & \text{addition} \\
  & \mid & e \text{ or } e & \text{boolean or} \\
  & \mid & e < e & \text{less than} \\
  & \mid & \ldots &
\end{array}
$$

and statements:

$$
\begin{array}{rcll}
S(Smt) & ::= & x := expr & \text{assign} \\
  & \mid & skip & \text{do nothing} \\
  & \mid & S_1 ; S_2 & \text{sequence} \\
  & \mid & \texttt{if } b \texttt{ then } S_1 \texttt{ else } S_2 & \text{test} \\
  & \mid & \texttt{while } b \texttt{ do } S \texttt{ done} & \text{loop}
\end{array}
$$

Code generation for expressions, example

e ::= c (cte expr)	`dr <-new_tmp()`
	`code.add(InstructionLI(dr, c))`
	`return dr`

- this rule gives a way to generate code for any constant.

Code generation for a boolean expression, example

e ::= $e_1 < e_2$	`dr <-new_tmp()`
	`t1 <- GenCodeExpr(e1)`
	`t2 <- GenCodeExpr(e2)`
	`endrel <- new_label()`
	`code.add(InstructionLI(dr, 0))`
	`#if t1>=t2 jump to endrel`
	`code.add(InstructionCondJUMP(endrel, t1, ">=" , t2)`
	`code.add(InstructionLI(dr, 1))`
	`code.addLabel(endrel)`
	`return dr`

- integer value 0 or 1.

Second example: a boolean test

Let us generate the code for $x < 4$:

```
li temp3, 4     // get 4
li  temp2, 0
geq temp0, temp3, lbl0  # >= comp + jump
li  temp2, 1
lbl0:
```

(temporary values on board)

Code generation for commands, example

if b **then** $S1$ **else** $S2$	`lelse,lendif <-new_labels()`
	`t1 <- GenCodeExpr(b)`
	`#if the condition is false, jump to else`
	`code.add(InstructionCondJUMP(lelse, t1, "=", 0))`
	`GenCodeSmt(S1) #then`
	`code.add(InstructionJUMP(lendif))`
	`code.addLabel(lelse)`
	`GenCodeSmt(S2) #else`
	`code.addLabel(lendif)`

Example for tests.

Let us generate the code for `if x<4 then y=7 else ...`

```
## preceding code
beq tmp2, zero, lelse1 # if false, jump
li temp4, 7
mv temp1, temp4    # y gets 7
jump lendif1
lelse1:
  # code for else branch
lendif1:
```

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From 3@ code to valid RISCV

3@code is not valid RISCV code !

3 “kinds of allocation”:

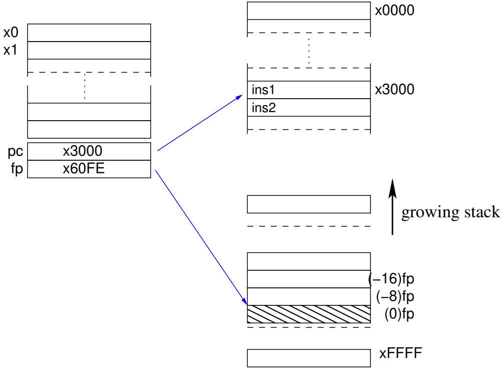
- All in registers (but ?) $place_i \rightarrow register$
- All in memory (here!) $place_i \rightarrow memory$
- Something in the middle (later!)

A stack, why ?

- Store constants, strings, . . .
- Provide an easy way to communicate arguments values (see later)
- Give place to store intermediate values (here)

Stack with RISCV

- There is a special register `fp`.
- Store and loads from `fp`



Nice picture by N. Louvet - adapted in 2019

How to store into the stack

Store (the content of) s_3 on the stack at offset $offset$!:

```
sd s3, -offset*8(fp)  # (Instru3A('sd', s3, Offset(
   FP, -offset*8)))
    # "write the value of s3 at address fp - offset
   *8"
```

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Code Generation

Input: a MiniC file:

```
int main(){
int n;
n=6;
return 0;}
```

Output: a RISCV file:

```
  [...]
        ;; (stat (assignment n = (expr (atom 6)) ;))
        li t1, 6     ; t1 is a riscv register.
        mv t2, r1
  [...]
```

Steps

- 3-address code generation according to the code generation rules.
- Simple register/memory allocation + pretty print.

Details in the dedicated video/slides.

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Drawbacks of the former translation

Drawbacks:

- redundancies (constants recomputations, . . .)
- memory intensive loads and stores.

► we need a more efficient data structure to reason on: **the control flow graph (CFG)**. (see next course)

Summary : 3adress code generation

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