Check-In

Review: Activation Records

Show the layout of an activation record with two 64-bit locals. Write the function prologue and epilogue corresponding to that function

Announcements

Administrivia

P5 officially extended

Q3 imminent!

University of Kansas | Drew Davidson

Statement Code Generation

Last Lecture

Activation Records

Managing the Stack

- Managing data
- Managing control

You Should Know

How to code up stack frames
The function prologue
The function epilogue

Architecture

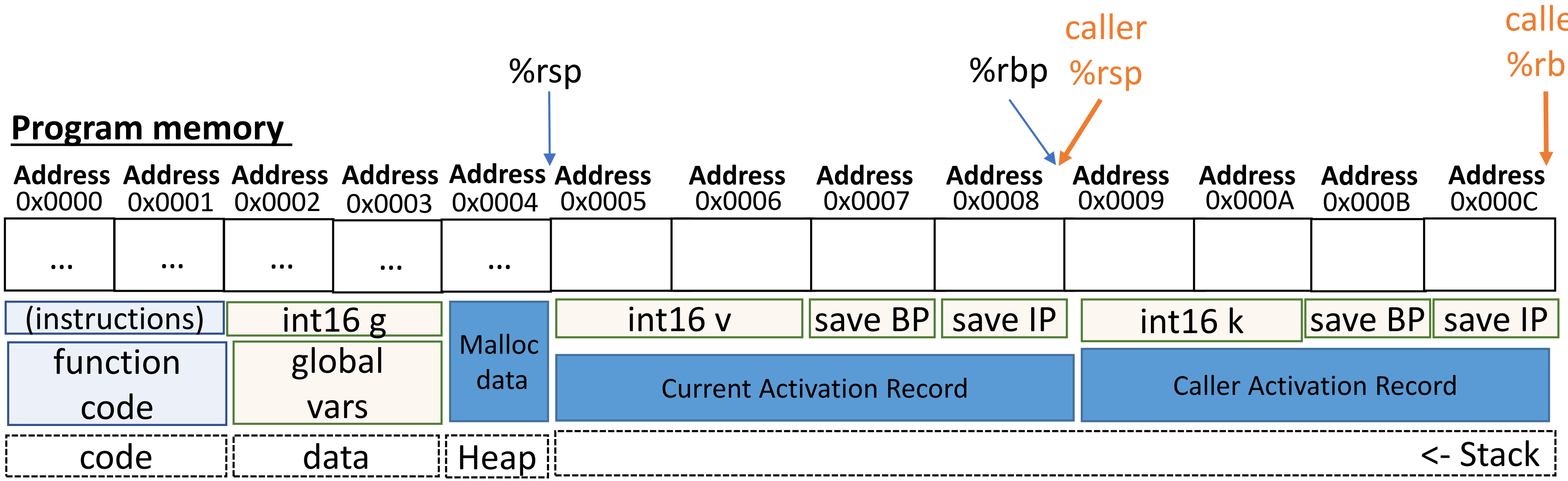
Call Stack Bookkeeping

Review: Stack Frames

We need to store (on the stack):

- The call site to resume execution after call
- The base pointer to restore the old stack frame after call

bookkeeping space at the beginning of the AR



Program memory

%rsp

%rbp

caller %rsp

caller %rbp

Address 0x0000	Address 0x0001	Address 0x0002	Address 0x0003	Address 0x0004	Address 0x0005	Address 0x0006	Address 0x0007	Address 0x0008	Address 0x0009	Address 0x000A	Address 0x000B	Address 0x000C
…	…	…	…	…								

(instructions)

function code

int16 g

global vars

Malloc data

int16 v

save BP

save IP

Current Activation Record

int16 k

save BP

save IP

Caller Activation Record

code

data

Heap

<- Stack

A Less-Trivial x64 Program

Review: Stack Frames

```
g : int;
v : () void {
  local : int;
  g = g - 1;
  local = g;
  give local;
}
main : ()int {
  g = 2;
  v();
};
```

Addressing modes

Toward Local Variables

Some Nice "Shortcuts"

- Often want to read memory at a fixed offset from some register

  "the memory at 8 bytes before %rbp"

- Good news! X64 can do that:

```
movq -8(%rbp), %rax
```

- This is a very handy addressing mode

```
leaq -8(%rbp), %rax
```

"Move the value AT %rbp – 8 into %rax" = **movq %rbp, %rdx**
subq $8, %rdx
movq (%rdx), %rax

"Move the value OF %rbp – 8 into %rax" = **movq %rbp, %rdx**
subq $8, %rdx
movq %rdx, %rax

Where We're At

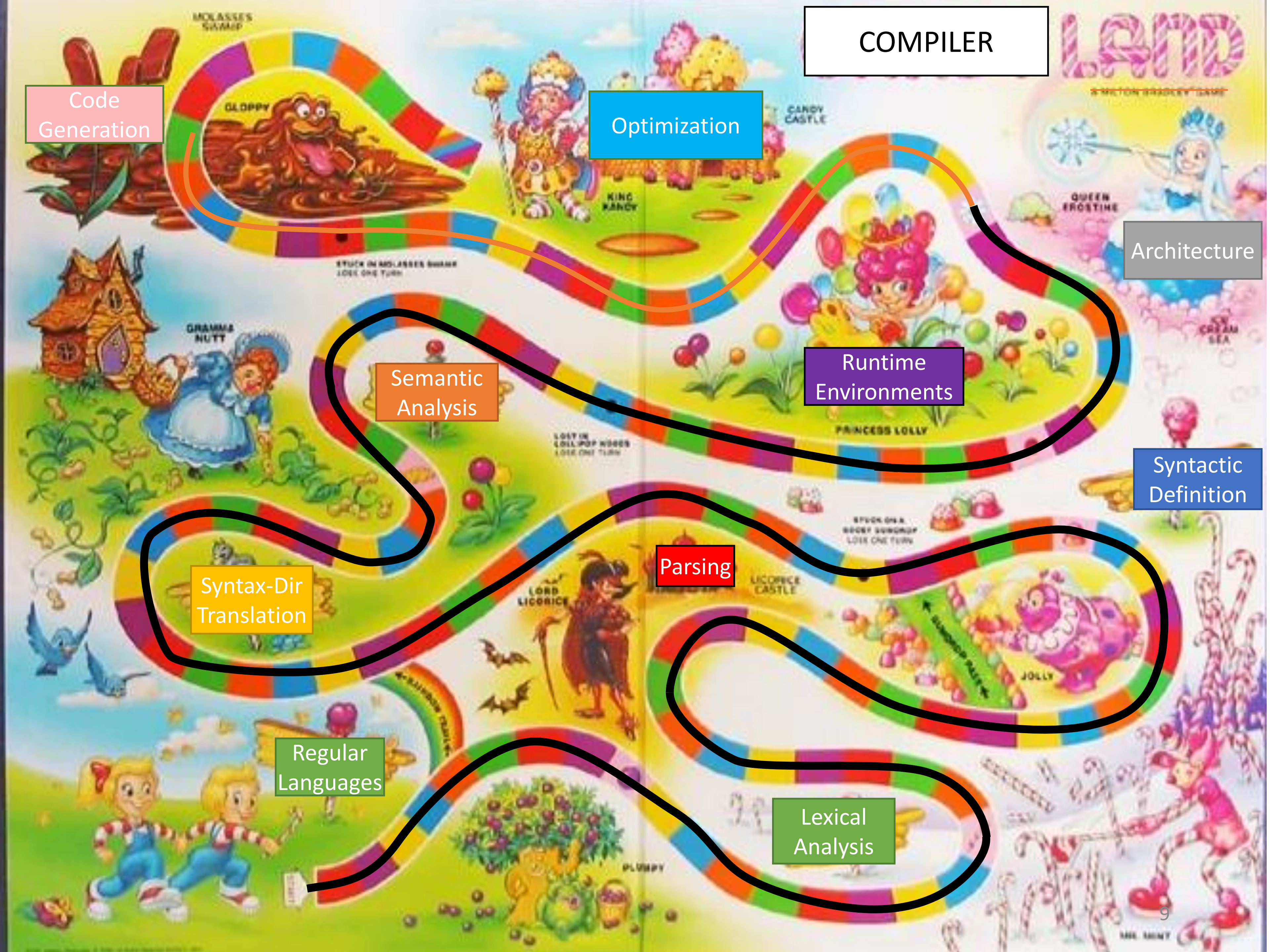
Progress Pics

Assembled quite a few x64 concepts

- Basic data manipulation (movq)
- Basic math (addq, idivq, etc)
- Global data (.data, .quad, .byte)
- Local data
- Function calls

You can now hand-code some non-trivial programs

COMPILER



Code Generation

Optimization

Architecture

Semantic Analysis

Runtime Environments

Syntactic Definition

Parsing

Syntax-Dir Translation

Regular Languages

Lexical Analysis

Lecture Outline

Statement Code Generation

From Quads to Assembly

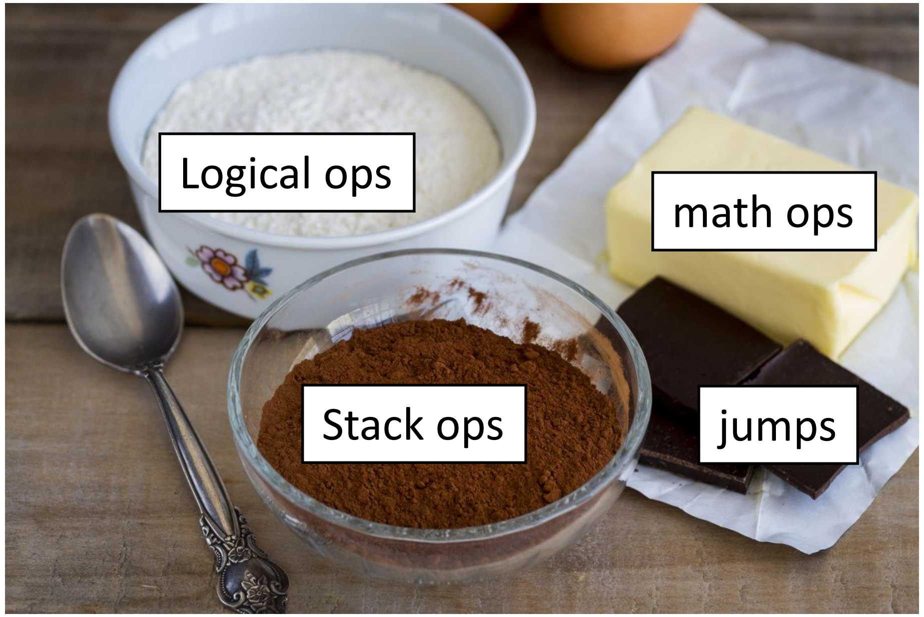
- Approach Overview
- Planning out memory
- Writing out x64

Code generation

Representing Abstract Constructs

Statement Code Generation

Combine (simple) target language constructs…



…to build (complex) source language constructs

Our Approach: Small Steps

Code Generation

2 passes over IRProgram (like passes over AST)

1. Allocate memory for opds (data pass)
2. Generate code for quads (code pass)

Code Generation Objectives

Designing Code Generators

- Two high level goals:
  - Generate correct code ← Top priority
  - Generate efficient code

- It can be difficult to achieve both at once
  - Efficient code can be harder to understand
  - Efficient code may have unanticipated side effects

Our Approach: Small Steps

Code Generation

2 passes over IRProgram (like passes over AST)

1. Allocate memory for opds (data pass)
2. Generate code for quads (code pass)

Preparing the 3AC memory layout

Variable Allocation

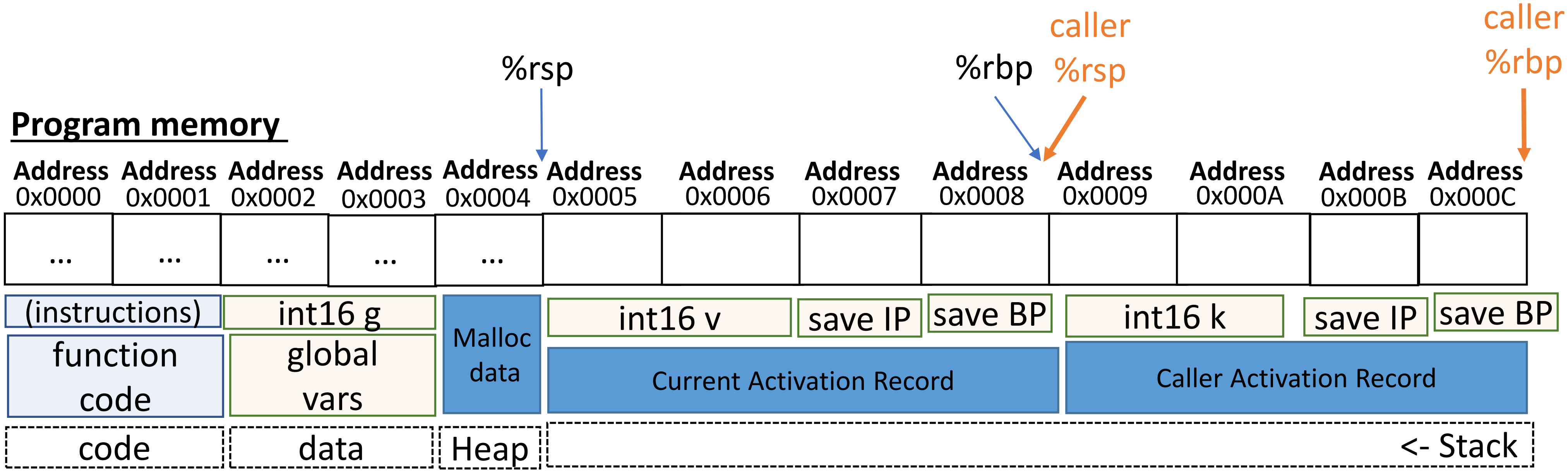
Code Generation

Big picture:

- Every variable needs space in enough space in memory for its type
- Every quad using that variable needs to access the same location

Need a mix of static/dynamic allocation

- Put globals/strings at fixed addresses in memory (absolute locations)
- Put locals/formals at stack offsets in memory (relative locations)



Program memory

Address 0x0000	Address 0x0001	Address 0x0002	Address 0x0003	Address 0x0004	Address 0x0005	Address 0x0006	Address 0x0007	Address 0x0008	Address 0x0009	Address 0x000A	Address 0x000B	Address 0x000C
…	…	…	…	…								

%rsp

%rbp

caller %rsp

caller %rbp

(instructions)

function code

int16 g

global vars

Malloc data

int16 v

save IP

save BP

Current Activation Record

int16 k

save IP

save BP

Caller Activation Record

code

data

Heap

<- Stack

Allocation: In Code (suggestion)

Add a location field (std::string) to semantic symbols

- All related SymOpds have pointers to the same symbol

Location can be a string

- For globals, the label that you'll write
- For locals, the stack offset you'll arrange

Variable Allocation: Globals

Code Generation

3AC Code

```
[g] := 4
```

Where g is a global int

location: At label gbl_g

X64 Code

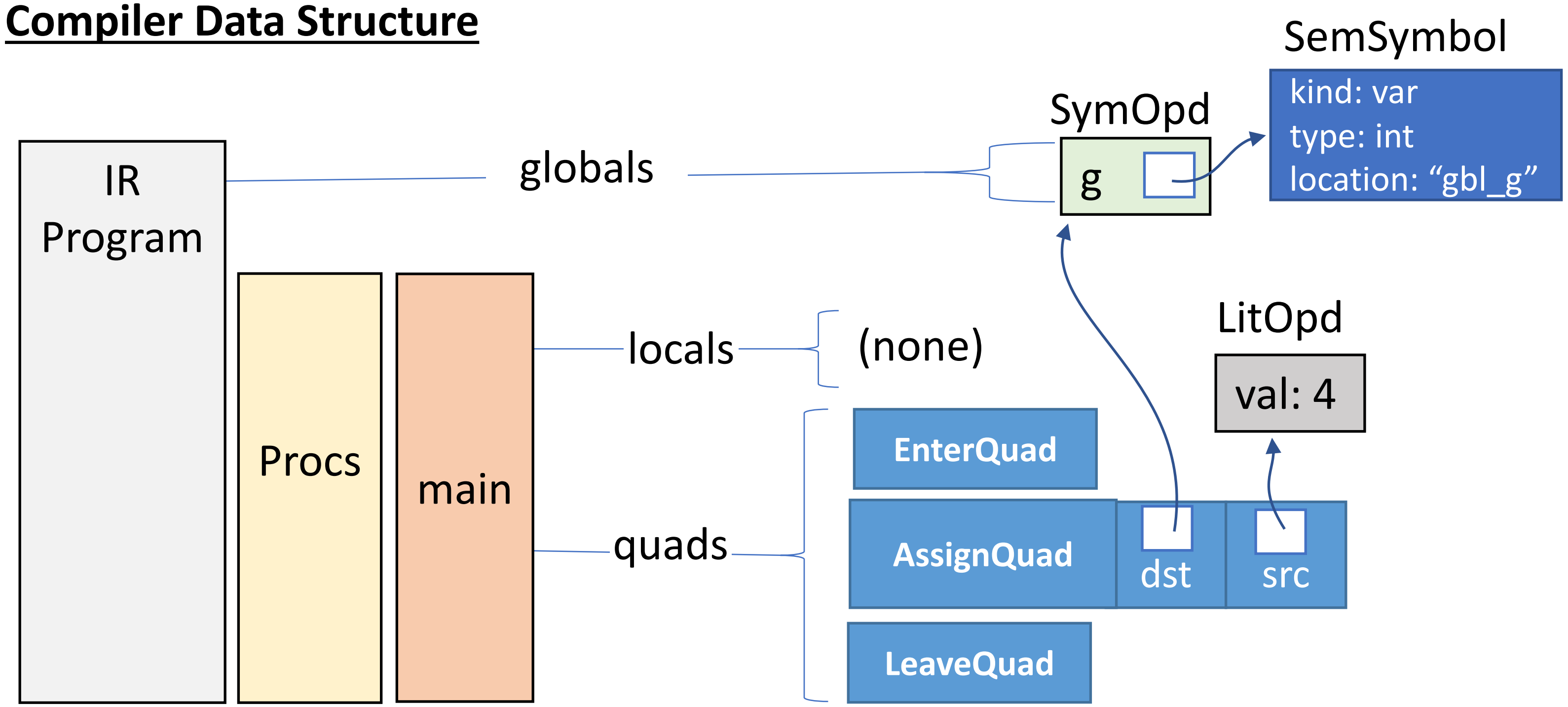
… in .data section …

```
gbl_g:     .quad 0
```

… somewhere in .text section …

```
movq $4, (gbl_g)
```

Compiler Data Structure



Variable Allocation: Locals

Code Generation

3AC Code

```
[v] := 7
```

Where v is a local int

location:
At offset
-24(%rbp)

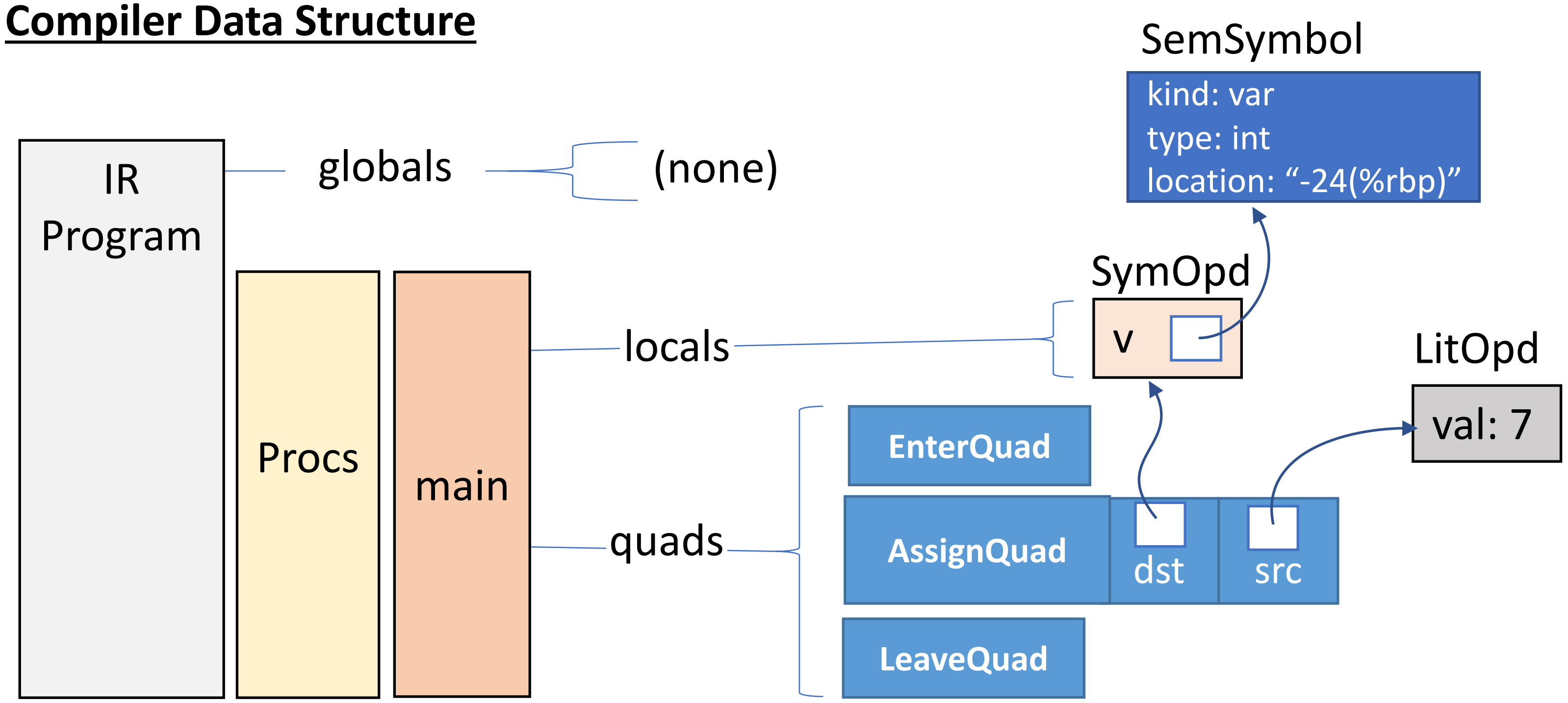
X64 Code

… assume stack frame setup …

… somewhere in main's asm …

```
movq $7, -24(%rbp)
```

Compiler Data Structure



SemSymbol

kind: var
type: int
location: "-24(%rbp)"

IR Program

globals

(none)

Procs

main

locals

SymOpd

v

LitOpd

val: 7

quads

EnterQuad

AssignQuad

dst

src

LeaveQuad

Our Approach: Small Steps

Code Generation

2 passes over IRProgram (like passes over AST)

1. Allocate memory for opds (data pass)
2. Generate code for quads (code pass)

Write the assembly file

Assembly Directives/Initialization

Code Generation

We're gonna write the whole file in one shot

- Aided greatly by our preparatory layout pass
- Also aided by the assembler

Write out .data section:

```
.data
.globl: main
<global1_label> : <global1_type> <global1_val>
…
<global1_label> : <global1_type> <global1_val>
```

Walk each 3AC Procedure, output each quad

```
enter main
```

Generating Code for Quads

Code Generation

Compiling

Generating Code for Quads

Code Generation

```
enter <proc>
leave <proc>
<opd> := <opd>
<opd> :=  <opr>  <opd>
<opd> := <opd>  <opr>  <opd>
<lbl>: <INSTR>
ifz <opd> goto <lbl>
goto Li
 nop
call <name>
setin <int> <operand>
getin <int> <operand>
setout <int> <operand>
getout <int> <operand>
```

Generating Code for Quads: enter/leave

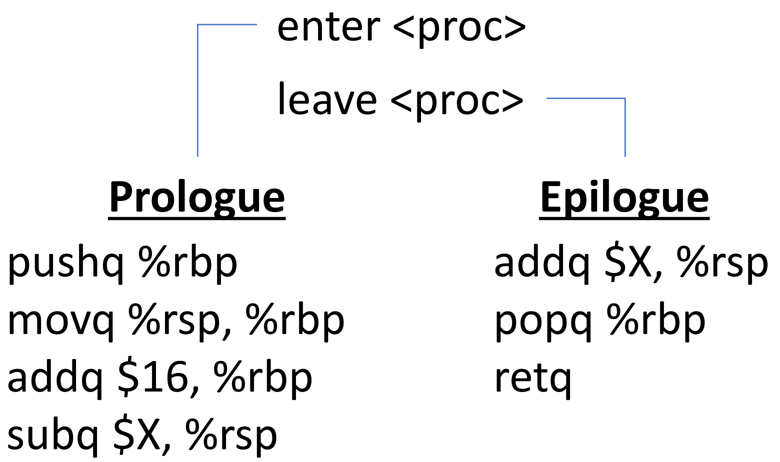
Code Generation

On entry to the function:

- Set up the activation record

On exit from the function

- Break down the activation record



enter <proc>

leave <proc>

Prologue

```
pushq %rbp
movq %rsp, %rbp
addq $16, %rbp
subq $X, %rsp
```

Epilogue

```
addq $X, %rsp
popq %rbp
retq
```

Make function prologue/epilogue

Generating Code for Quads: enter/leave

Code Generation

enter <proc>

leave <proc>

Prologue

```
pushq %rbp
movq %rsp, %rbp
addq $16, %rbp
subq $X, %rsp
```

Epilogue

```
addq $X, %rsp
popq %rbp
retq
```

src code

```
int main(){
}
```

3ac code

```
enter main
leave main
```

asm code

```
lbl_main: pushq %rbp
          movq %rsp, %rbp
          addq $16, %rbp
          subq $0, %rsp
          addq $0, %rsp
          pushq %rbp
          retq
```

Generating Code for Quads

Code Generation

✓ enter <proc>

✓ leave <proc>

<opd> := <opd>

<opd> := <opr> <opd>

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

<lbl>: <INSTR>

ifz <opd> goto <lbl>

goto Li

nop

call <name>

setin <int> <operand>

getin <int> <operand>

setout <int> <operand>

getout <int> <operand>

For assignment-style quads…

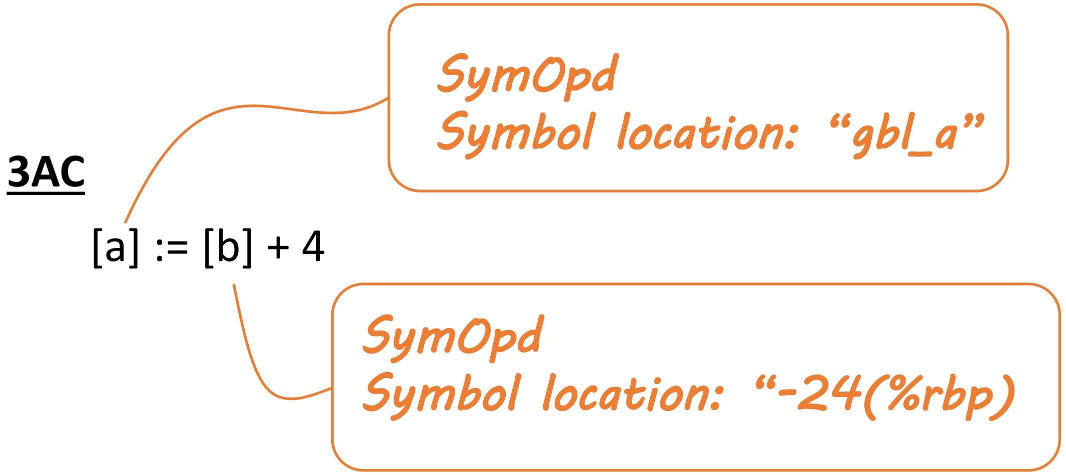
1) Load operand src locations into registers

2) Compute a value to register

3) Store result at dst location

Assignment-Style Quads

Code Generation



3AC

[a] := [b] + 4

SymOpd
Symbol location: “gbl_a”

SymOpd
Symbol location: “-24(%rbp)

ASM

1) `movq -24(%rbp), %rax`

1) `movq $4, %rbx`

2) `addq %rbx %rax`

3) `movq %rax (gbl_a)`

For assignment-style quads…

1) Load operand src locations into registers

2) Compute a value to register

3) Store result at dst location

[a] := [b] [illegible] 4

Questions?

Code Generation

4/3 - Lec

4/5 - Lec (ReviewSession)

w8 freebee
with video

4/7 - Q3

4/10 - Lec

4/12 - Lec

4/14 - Flipped Friday