CS 314 Principles of Programming Languages

Lecture 11

Zheng Zhang

Department of Computer Science
Rutgers University

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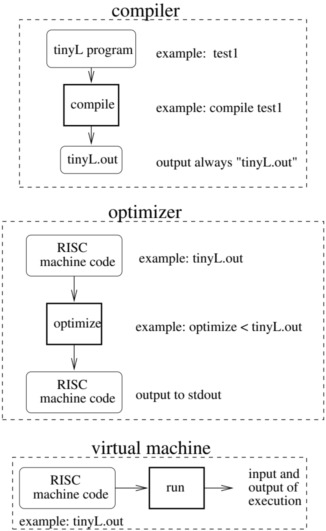
Class Information

- Homework 4 due this Friday 11:55pm.
- Project 1 is posted, due Sunday 10/23 11:55pm.

Project 1: Overview



Project 1: Dead Code Elimination

Redundant Code Elimination: Eliminate code without changing the semantics of the program. If the execution of an operation or instruction does not contribute to the input/output behavior of the program, the instruction is considered dead code and therefore can be eliminated.

Example:

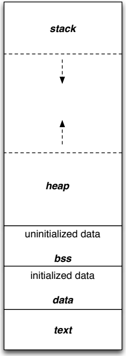
Original Code	**Optimized Code**
`LOADI Rx #c1`	`LOADI Rx #c1`
`LOADI Ry #c2`	`LOADI Ry #c2`
`LOADI Rz #c3`	`ADD R1 Rx Ry`
`ADD R1 Rx Ry`	`STORE a R1`
`MUL R2 Rx Ry`	`WRITE a`
`STORE a R1`	
`WRITE a`	

See project description for more details.

Review: Program Memory Layout

Review: Storage Management

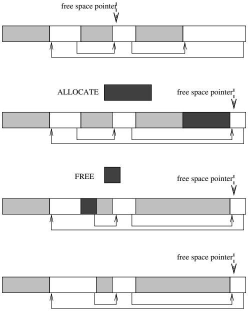
- *S*tatic objects are given an absolute address that is retained throughout program's execution
- *S*tack objects are allocated and deallocated in last-in, first-out order, usually in conjunction with subroutine calls and returns.
- *H*eap objects may be allocated and deallocated at arbitrary times.



Maintaining Free List

- **allocate**: continuous block of memory; remove space from free list (here: linked list).

- **free**: return to free list after coalescing with adjacent free storage (if possible); may initiate compaction.



Review: What went wrong?

“Aliasing” and freeing memory

```
#include <stdio.h>
#include <stdlib.h>
int main(void)
{
  int *a = NULL; int *b = NULL; int *c = NULL;

  a = (int *) malloc(sizeof(int));
  b = a; *a = 12;
  printf("%x %x: %d\n", &a, a, *a);
  printf("%x %x: %d\n", &b, b, *b);
  free(a);
  printf("%x %x: %d\n", &b, b, *b);

  c = (int *) malloc(sizeof(int));
  *c = 10;
  printf("%x %x: %d\n", &c, c, *c);
  printf("%x %x: %d\n", &b, b, *b);
}
```

```
 > a.out
effff60c 209d0: 12
effff608 209d0: 12
effff608 209d0: 12
effff604 209d0: 10
effff608 209d0: 10
```

What went wrong?

Use a subroutine to create an object

```
#include <stdio.h>
#include <stdlib.h>

/* TYPE DEFINITION */
typedef struct cell listcell;
struct cell
{ int num;
  listcell *next;
};

listcell *head = NULL;

listcell *create_listcell() {
  listcell new;
  new.num = -1; new.next = NULL;
  return &new;
}

int main (void) {
  head = create_listcell();
  printf("head->num = %d\n", head->num);
}


\em
> gcc stack.c
˜ stack.c: In function ‘create\_listcell’:
˜ stack.c:17: warning: function returns address of local variable
> ./a.out
head->num = -1
```

What went wrong?

Use a subroutine to create an object: malloc

```
#include <stdio.h>
#include <stdlib.h>

/* TYPE DEFINITION */
typedef struct cell listcell;
struct cell
{ int num;
  listcell *next;
};

listcell *head = NULL;

listcell *create_listcell() {
  listcell *new;
  new = (listcell *) malloc(sizeof(listcell));
  new->num = -1; new->next = NULL;
  return new;
}

int main (void) {
  head = create_listcell();
  printf("head->num = %d\n", head->num);
}
```

> *gcc heap.c*
> *./a.out*

head→num = -1

Review: Pointers and Arrays in C

Pointers and arrays are similar in C:

- array name is pointer to a[0]:

  after

  int a[10];
  *int *pa;*
  pa = &a[0];

  pa and a have the same semantics
- pointer arithmetic is array indexing

  pa+1 and a+1 point to a[1]
- exception: an array name is not a variable

  a++ is ILLEGAL
  a=pa is ILLEGAL (pa=a is LEGAL!)

Scott: Chap. 3.1 - 3.4; ALSU Chap. 7.1 - 7.3

What's in a name? — each name "means" something!

- denotes a programming language construct
- has associated "attributes" (e.g.: type, memory location, read/write permission, storage class, access restrictions, etc.)
- has a meaning, i.e., represents a semantic object (e.g.: a type description, an integer value, a function value, a memory address, etc.)

Binding – association of a name with the thing it "names" (e.g., a name and a memory location, a function name and its "meaning", a name and a value)

- **Compile time** – during compilation process – static (e.g.: macro expansion, type definitions)
- **Link time** – separately compiled modules/files are joined together by the linker (e.g., adding the standard library routines for I/O (stdio.h), external variables)
- **Run time** – when program executes – dynamic

Compiler needs bindings to know meaning of names during translation (and execution).

Binding Times - Choices

- **Early binding** times – more efficient (faster) at runtime
- **Late binding** times – more flexible (postpone binding decision until more "information" is available)
- Examples of static binding (early):
  - functions in C
  - types in C
- Examples of dynamic binding (late):
  - method calls in Java
  - dynamic typing in JavaScript, Scheme

Note: dynamic linking is somewhat in between static and dynamic binding; the funtion signature has to be known (static), but the implementation is linked and loaded at run time (dynamic).

How to Maintain Bindings

- symbol table: maintained by compiler during compilation
  names $\Rightarrow$ **attributes**
- environment: maintained by compiler generated code during program execution
  names $\Rightarrow$ **memory locations**

Questions

- How long do bindings for a name hold in a program?
- What initiates a binding?
- What ends a binding?

Scope Example

Algol-like Programming Languages

```
program L;
   var n: char;     {n declared in L}

   procedure W;
   begin
     write(n);      {n referenced in W}
   end;

   procedure D;
      var n: char; {n declared in D}
   begin
      n:= 'D';      {n referenced in D}
      W
   end;

begin
  n:= 'L';          {n referenced in L}
  W;
  D
end.
```

Lexical Scope

- Non-local variables are associated with declarations at *compile* time
- Find the smallest block syntactically enclosing the reference and containing a declaration of the variable

- Example:
  - The reference to `n` in `W` is associated with the declaration of `n` in `L`
  - The output is?

Dynamic Scope

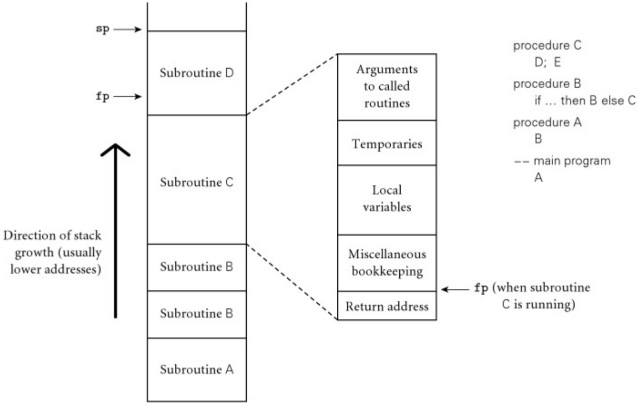
- Non-local variables are associated with declarations at *run* time
- Find the most recent, currently active run-time stack frame containing a declaration of the variable

- Example:
  - The reference to `n` in `W` is associated with two different declarations at two different times
  - The output is?

Procedure Activations

- Begins when control enters activation (call)
- Ends when control returns from activation

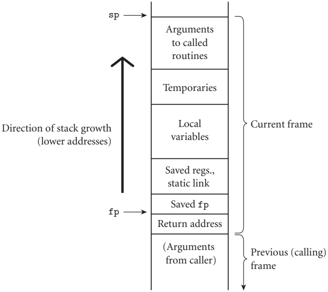
Example:



Stack Frame, Activation Record

Scott: Chap. 9.1 - 9.3; ALSU Chap. 7.1 - 7.3

- Run-time stack contains frames for main program and each active procedure.
- Each stack frame includes:
  1. Pointer to stack frame of caller (control link for stack maintainance and dynamic scoping)
  2. Return address (within calling procedure)
  3. Mechanism to find non-local variables (access link for lexical scoping)
  4. Storage for parameters, local variables, and final values



Next Lecture

Things to do:
Start working on the project. Due Sunday October 23.

Read Scott: Chap. 3.1 - 3.4, 9.1 - 9.3 ;

Next time:

- Access link and display, parameter passing styles and their implementation.