CS212

"C Practicum"

Heap
Pointers
Fall 2005

Announcements

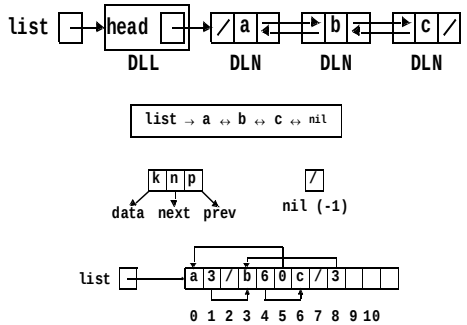
- P2b grades Mon
- P3 split into 2 parts:
  - A: document/proposal
  - B: full grammar (all syntax, semantics)

Overview

- The Heap:
  - Simulating Objects
  - JVM and The Heap
  - SaM's Heap
- Pointers:
  - definition
  - declaration
  - addressing
  - dereferencing
  - examples

Simulating Objects

An example:

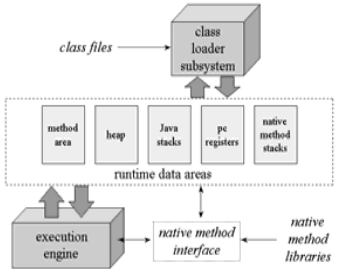


Example demonstrates needs to dynamically allocate memory that we can access and remove as neded.

So, where do the objects in memory go....?

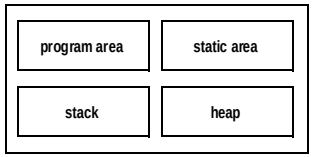
JVM and OOP

JVM



Simplification

from: http://www.artima.com/insidejvm/ed2/jvm2.html



How about SaM?

SaM's Heap

- Allocation of heap in SaM:
  - ***object*** = chunk of memory in heap
  - address = beginning of chunk
  - no functions in Heap!

- Object starts at first cell
- Fields in cells
- Can use some cells for other info...

Stack ↔ Heap?

- How to connect object to Stack?
  - when allocating object, store first cell address on Stack
  - refer to fields of object with that address
- Picture:

Example Samcode for Heap

- Use memory allocation Samcode instruction: **MALLOC**!
  - pops top of Stack
  - allocates that **number of cells** in heap
  - pushes the address of the first cell onto stack
  - SP++
- Example (**heap.sam**):

```
PUSHIMM 1   // 1 cell to allocate
MALLOC      // pop 1 and allocate 1 cell in heap
PUSHIMM 3   // 3 cells to allocate
MALLOC      // pop 3 and allocate 3 cells in heap
PUSHIMM 0   // no cells to allocate
MALLOC      // pop 0 and allocate no cells in heap
FREE        // deallocate last "object"
FREE        // deallocate second "object"
FREE        // deallocate first "object"
PUSHIMM 0   // push dummy return value
STOP        // cease execution
```

Bali and C

- Borrowing from C!
  - Syntax roughly equivalent to Java
  - http://computer.howstuffworks.com/c.htm (and others)
  - See Tools lecture... Cygwin and C compiler
- Need to deal with pointers...why?
  - pointers part of grammar
  - interested in ***dynamically allocated memory***
    - what is it? (see example below)
    - why bother?

Example) Java objects

```
Person p = new Person();
Person q = p;
q.name = "Dimmu Borgir"
```


C Pointers

- Declare variables as pointer types
  - ***Type* p***
  - ***p*** is **pointer to type *Type***
  - how does SaM represent "memory type"?
- Example) **`int* p`**
  - **`p`** is pointer to an **`int`**
  - sometimes you see **`int *p`** and **`int p*`**
- What does **`p`** actually store?
  - When initialized, **`p`** points to unknown location
  - After assigned, **`p`** points to another variable
- Picture of **`p`**:

Address Operator (&)

- How to store value in **`p`**?
  - Address operator **`&`**:
    - *address of ...*
    - *location of ...*
  - Yields an integer value:
    - the address of some variable is somewhere in memory
    - think of Stack cell addresses
- Example)

```
/* address.c */
int main(int argc, char* argv[]) {
  int* p; // declare pointer p to int
  int i;  // declare int i
  p = &i; // store address of i in p

  printf("%s%i\n","&i: ",&i);
  printf("%s%i\n","p:  ",p);
  printf("%s%i\n","&p: ",&p);
}
```

Output:

```
&i: -4196924
p:  -4196924
&p: -4196920
```

Picture to relate **`p`** and **`i`**?

Dereferencing/Indirection Operator (*)

- Reminders:
  - ***Type* var***
  - ***var*** points to an address of ***Type***
- ***Deferencing operator***: **`*`**
  - **`*p`** dereferences **`p`** to access location to which **`p`** points
  - Since value stored in **`p`** is an address (memory location), **`*p`** is the indirect value of **`p`** (the value stored at that address).
- Complication:
  - **`*p`** depends on "side" of assignment: ***L-value***, ***R-value***
  - brief examples:

```
*p = 10
q = *p + 10
```

L-Value (*p = *RHS*)

- *L-value*:
  - deference the address that **p** stores, and put the RHS of the assignment there
  - abbreviated: *put* RHS where ***p** points
- Example:

```
int* p;   // declare pointer p to int
int v;    // declare int v
p = &v;   // store address of v in p
          // or say, "p points to v"
*p = 10;  // deference p and put 10 in that address
          // or say, "store 10 where p points"
```

- Picture:

R-Value (*LHS* = *p)

- *R-value*:
  - deference the address that **p** stores, and retrieve the value stored there
  - abbreviated: *get* the value from where ***p** points
- Example:

```
int* p;     // declare pointer p to int
int v;      // declare int v
p = &v;     // store address of v in p
*p = 10;    // store 10 where p points
int x;      // declare int x
x = *p+2;   // retrieve value at address pointed to by p
            // and add 2
printf("%i",*p); // is this L- or R-value?
```

- Picture:

Aliases

- Akin to OOP:
  - multiple pointers pointing to same location
  - changing the stored value affects both "aliased" pointers

Picture?

```
/* alias example */

int main(int argc, char* argv[]) {
  int i, *p, *q;

   p = &i ;
  *p = 30 ;
   q = p  ; /* what happens here? */
  *q = 40 ;

  printf("%s%i\n","*p: ",*p);
  printf("%s%i\n","*q: ",*q);
  printf("%s%i\n","i:  ", i);
}

/* Output? */
```


Two More Details

- Derefencing and addressing are inverse operations:

```
/* identity example */
int main(int argc, char* argv[]) {
  int i, x;
  x = 50;
  i = *&x;
  printf("%s%i\n","p:  ",i);
  printf("%s%i\n","p:  ",x);
}
```

- **NULL** pointer:

```
/* NULL example */
# include "stddef.h"
int main(int argc, char* argv[]) {
  int *p, x;
  printf("%s%i\n","p:",p);
  p = NULL;
  printf("%s%i\n","p:",p);
}
```