Pointers

CS 217

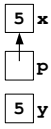
Pointers

- Variables whose values are the addresses of variables
- Operations
  - "address of" (reference) `&`
  - "indirection" (dereference) `*`
  - arithmetic `+, -`
- Declaration mimics use
  - `char *p;` ⟶ `*p` is a `char`, so `p` is a pointer to a `char`

Pointers (cont)

- Suppose `x` and `y` are integers and `p` is a pointer to an integer…

```
int x, y
int *p;
p = &x;        p gets the address of x
y = *p;        y gets the value pointed to by p
y = *(&x);     same as y = x
```



Pointers (cont)

- Pointers (e.g., `*p`) are variables

```
int x, y;
int *px, *py;
px = &x;          px is the address of x
*px = 0;          sets x to 0
py = px;          py also points to x
*py += 1;         increments x to 1
y = (*px)++;      sets y to 1, x to 2
```

Pointer Arithmetic

- Pointer arithmetic takes into account the stride (size of) the value pointed to

```
char *p;
p += i;   increments p by i elements
p -= i;   decrements p by i elements
p++;      increments p by 1 element
p--;      decrements p by 1 element
```

- If `p` and `q` are pointers to same type

```
p - q     number of elements between p and q
```

- Other ops: `p < q;  <= == != >= >`
  - `p` and `q` must point to the same array
  - no runtime checks to ensure this

Pointers & Arrays

- Array names are constant pointers

```
int a[10];
int *p;
p = a;        p points to a[0]
a++;          illegal; can't change a constant
p++;          legal; p is a variable
```

- Subscripting is defined in terms of pointers

```
a[i]      *(a+i)
&a[i]     a+i

p = &a[0]    &*(a+0)    &*a    a
```

Pointers & Arrays

- Pointers can "walk along" arrays

```
int a[10], i, *p, x;
p = a;          p gets &a[0]
x = *p;         x gets a[0]
p = p + 1;      p points to a[1]
y = *p;         x gets a[1]
p++;            p points to a[2];
```

Pointers & Strings

- String constants denote constant ptrs to actual chars

```
char *msg = "HELLO";
```

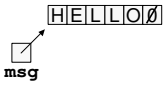
and

```
char msg[] = "HELLO";
char *p = msg;
```

`p` points to 1st character of `"HELLO"`

- Strings can be used whenever arrays of chars are used

```
static char digits[] = "0123456789";
putchar(digits[i]);
```



Argument Passing

- Passing pointers to functions simulates passing arguments "by reference"

```
void swap(int x, int  y)
{
   int t;

   t = x;
   x = y;
   y = t;
}

int a = 1, b = 2;
swap(a, b);
printf("%d %d\n",a,b);
```

Passing by value

```
void swap(int *x, int  *y)
{
   int t;

   t = *x;
   *x = *y;
   *y = t;
}

int a = 1, b = 2;
swap(&a, &b);
printf("%d %d\n",a,b);
```

Passing by reference

Pointer & Array Parameters

- Array parameters:
  - formals are not constant; they are variables
  - passing an array passes a pointer to 1st element
  - arrays (and only arrays) are passed "by reference"

```
void f(T a[]) {. . .}
```
is equivalent to
```
void f(T *a) {. . .}
```

Example

- Copying strings

```
void scopy(char *s, char *t)
```
copies `t` to `s`

- Array version

```
void scopy(char s[], char t[]) {
   int i;
   for (i = 0; t[i]; i++) s[i] = t[i];
}
```

- Pointer version

```
void scopy(char *s, char *t) {
   while (*t)
      *s++ = *t++;
}
```

Arrays of Pointers

- Used to build tabular structures
- Indirection (`*`) has lower precedence than `[]`

```
char *line[100];
```
same as
```
char *(line[100]);
```
declares array of pointers to strings
```
*line[i]
```
refers to the 0th character of the ith string

Arrays of Pointers (cont)

- Can be initialized
- Example

```
char *name[] = {
  "January",
  "February",
  . . .,
  "December"
};
```

- Another example

```
int a, b;
int *x[] = {&a, &b, &b, &a, NULL};
```

Arrays of Pointers (cont)

- Similar to multi-dimensional arrays

```
int a[10][10];
int *b[10];
```

both `a[i][j]` and `b[i][j]` are legal references to `int`s

- Array `a`:
  - 2-dimensional 10x10 array
  - storage for 100 elements allocated at compile time
  - `a[6]` is a constant; `a[i]` cannot change at runtime
  - each row of `a` has 10 elements
- Array `b`:
  - an array of 10 pointers; each element could point to an array
  - storage for 10 pointers allocated at compile time
  - values of these pointers must be initialized at runtime
  - `b[6]` is a variable; `b[i]` can change at runtime
  - each row of `b` can have a different length (ragged array)

Array of Pointers (cont)

- Another example

```
void f(int *a[10]);
```

is the same as

```
void f(int **a);
```

and

```
void g(int a[][10]);
```

is the same as

```
void g(int (*a)[10]);
```

`**a = 1;` is legal in both `f` & `g`

Command-Line Arguments

- By convention, `main` is called with 2 arguments

```
int main(int argc, char *argv[])
```

  `argc` is the number of arguments

  `argv` is an array of pointers to the arguments

- Example: `echo hello world`

```
argc = 3
argv[0] = "echo"
argv[1] = "hello"
argv[2] = "world"
argv[3] = NULL
```

Implementation of `echo`

```
int main(int argc, char *argv[]) {
   int i;
   for (i = 1; i < argc; i++)
      printf("%s%c",argv[i],
             (i < argc-1) ? ' ' : '\n');
   return 0;
}
```

Pointers to Functions

- Used to parameterize other functions

```
void SortStrings(char *v[], int n,
     int (*compare)(char *, char *)) {
   . . .
   if ((*compare)(v[i],v[j]) <= 0) {
      . . .
   }
   . . .
}
```

Pointers to Functions (cont)

- Declaration syntax can confuse:

```
int (*compare)(void *, void*)
```

declares `compare` to be a "pointer to a function that takes two `void *` arguments and returns an `int`"

```
int *compare(void *, void *)
```

declares `compare` to be a "function that takes two `void *` arguments and returns a pointer to an `int`"

Pointers to Functions (cont)

- Invocation syntax can also confuse:

```
(*compare)(v[i], v[j])
```

calls the function pointed to by `compare` with the arguments `v[i]` and `v[j]`

```
*compare(v[i], v[j])
```

calls the function `compare` with arguments `v[i]` and `v[j]`, then dereferences the value returned

- Function call has higher precedence than dereferencing

Pointers to Functions (cont)

- A function name itself is a constant pointer to a function (like an array name)

```
extern int strcmp(char *, char *);
main(int argc, char *argv[]) {
   char *v[VSIZE];
   . . .
   sort(v, VSIZE, strcmp);
   . . .
}
```

Pointers to Functions (cont)

- Arrays of pointers to functions

```
extern int mul(int, int);
extern int add(int, int);
. . .
int (*operators[])(int, int) = {
   mul, add, . . .
};
```

- To invoke

```
(*operators[i])(a, b);
```