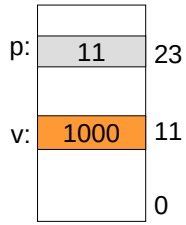
Pointers and Arrays

CS 217

Pointers

- What is a pointer
  - A variable whose value is the address of another variable
  - **p** is a pointer to variable **v**
- Operations
  - **&:** address of (reference)
  - ***:** indirection (dereference)
- Declaration mimics use
  - **int *p;**
    p is the address of an **int**
    (dereference **p** is an integer)
  - **int v;**
    p = &v;
    p stores the address of **v**



Pointer Operation Examples

- Examples of * and &

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

- Unary operators associate right to left

```
y = *&x;         /* same as y = *(&x) */
```

- Unary operators bind more tightly than binary ones

```
y = *p + 1;      /* same as y = (*p) + 1; */
y = *p++;        /* same as y = *(p++); */
```


More Pointer Examples

- References (e.g., *p) are variables

```
int x, y, *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        */
```

- What about the following?

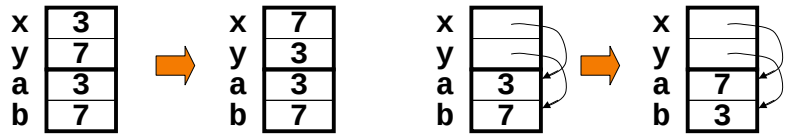
```
++*px
*px++
```

Argument Passing

- C functions pass arguments “by value”
- To pass arguments “by reference,” use pointers

```
void swap(int x, int  y)
{
    int t;
    t = x;
    x = y;
    y = t;
}
int a = 3, b = 7;
swap(a, b);
printf(“%d %d\n”,a,b);
```

```
void swap(int *x, int  *y)
{
   int t;
   t = *x;
   *x = *y;
   *y = t;
}
int a = 3, b = 7;
swap(&a, &b);
printf(“%d %d\n”,a,b);
```



Pointers and Arrays

- Pointers can “walk along” arrays

```
int a[10], *p, x;

p = &a[0];    /* p gets the address of a[0]    */
x = *p;       /* x gets  a[0]                  */
x = *(p+1);   /* x gets  a[1]                  */
p = p + 1;    /* p points to  a[1]             */
p++;          /* p points to  a[2]             */
```

- What about the following?

```
x = *p++;
x = ++*p;
```


Pointers and Arrays, cont’d

- Array names are constant pointers

```
int a[10], *p, i;
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), i[a]     /* Legal and the same          */
&a[i], a+i             /* Legal and the same          */
p = &a[0]              /* &*(a+0) → &*a → a           */
```

- Pointers can walk arrays efficiently

```
p = a;
for (i = 0; i < 10; i++)
    printf( “%d\n”, *p++ );
```


Pointer Arithmetic

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

```
long *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 T

```
p – q     /* number of elements between  p  and  q */
```

- Does it make sense to add two pointers?

Pointer Arithmetic, cont'd

- Comparison operations for pointers
  - `<, >, <=, >=, ==, !=`
  - `if (p < q) ... ;`
  - **p** and **q** must point to the same array
  - no runtime checks to ensure this
- An example

```
int strlen(char *s) {
   char *p;
   for (p = s; *p; p++)
      ;
   return p – s;
}
```


Pointer & 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) {. . .}
```


Pointers & Strings

- A C string is an array of "char" with NULL at the end
- String constants denote constant pointers to actual chars

```
char *msg = "now is the time";

char amsg[] = "now is the time";
char *msg = amsg;
    /* msg points to 1st character of "now is the time" */
```

- Strings can be used whenever arrays of chars are used

```
putchar("0123456789"[i]);

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


An Example: String Copy

- Array version

```
void scopy(char s[], char t[]) {
    int i = 0;
    while ((s[i] = t[i]) != '\0')
        i++;
}
```

- Pointer version

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

- Idiomatic version

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

Arrays of Pointers

- Used to build tabular structures
- Indirection "**`*`**" has lower precedence than "**`[]`**"
- Declare array of pointers to strings

```
char *line[100];
char *(line[100]);
```

- Reference examples

```
line[i]   /* refers to the i-th string */
*line[i]  /* refers to the 0-th char of the i-th string */
```


Arrays of Pointers, cont'd

- Initialization example

```
char *month(int n) {
    static char *name[] = {
        "January", "February", "March", "April",
        "May", "June", "July", "August",
        "September", "October", "November", "December"
    };

    assert(n >= 1 && n <= 12);
    return name[n-1];
}
```

- **Another example**

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


Arrays of Pointers, cont'd

- An array of pointers is a 2-D array

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

- Array a:
  - 2-dimensional 10x10 array
  - Storage for 100 elements allocated at compile time
  - Each row of a has 10 elements, cannot change at runtime
  - **`a[6]`** is a constant
- 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
  - Each row of **`b`** can have a different length (ragged array)
  - **`b[6]`** is a variable; **`b[i]`** can change at runtime

More Examples

- Equivalence example

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

- Another equivalance example

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

- Legal in both f and g:

```
**a = 1;
```

Command-Line Arguments

- By convention, **`main()`** is called with 2 arguments
  - **`int main(int argc, char *argv[])`**
  - **`argc`** is the number of arguments, including the program name
  - **`argv`** is an array of pointers to the arguments
- Example:

```
% echo hello
argc = 2
argv[0] = “echo”
argv[1] = “hello”
argv[2] = 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 sort(void *v[], int n,
     int (*compare)(void *, void *)) {
   . . .
   if ((*compare)(v[i],v[j]) <= 0) {
     . . .
   }
   . . .
}
```

- sort does not depend on the type of the object
  - Such functions are called polymorphic

Pointers to Functions, cont’d

- Use an array of `void*` (generic pointers) to pass data
- `void*` is a placeholder
  - Dereferencing a `void *` requires a cast to a specific type
- Declaration syntax can be confusing:
  - **`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'd

- 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);
    . . .
}
```

- Actually, both v and strcmp require a cast

```
sort((void **)v, VSIZE,
     (int (*)(void *, void*))strcmp);
```


Pointers to Functions, cont'd

- 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);
```


Summary

- Pointers
  - "type *" (`int *p`) declares a pointer variable
  - * and & are the key operations
- Operation rules
  - Unary operations bind more tightly than binary ones
  - Pointer arithmetic operations consider size of the elements
- Pointers and arrays have a tight relationship
  - An array is a constant pointer pointing to the 1st element
  - A pointer can walk through elements of an array
  - An array of pointers is a 2-D array (1-D fixed and another variable)
  - Master how to get command-line arguments from **`main()`**
- Pointers to functions
  - Can be used to parameterize functions