CS1100
Introduction to Programming

Structures

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Structures

- Collection of one or more variables, possibly of different types, grouped together under a single name for easy handling.
- For example - a structure which represents a point in a two dimensional plane

```
struct point{
    int x;
    int y;
};
```

A mechanism for defining compound data types

By itself it reserves no storage

Point in 2D → 2 Integers

- Different ways of declaring structure variables

```
struct point{
    int x;
    int y;
} point1, point2;
```

```
struct point point1, point2;
struct point point1 = {3, 2};
```


Marks and Names

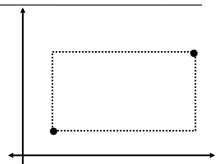
```
struct student{
    char *name;
    int mark;
}s1, s2;

struct student s1, s2;
struct student s1 = { "Ramesh" , 79 };
```

name could itself be a struct made up of first name, middle name and last name… *Nested structures are allowed*

A Rectangle

```
struct rectangle{
    struct point pt1;
    struct point pt2;
}rect1;
```



- Accessing points in the rectangle

```
rect1.pt1.x = 4;
rect1.pt1.y = 5;
```

Or

```
rect1.pt1 = { 4, 5 };
```


Defining New Types

- ‘ ’ keyword is used for creating new data types
- For example:

```
typedef int Age;
Age myAge = 99;
```

- typedef and Structures:

```
typedef struct point pointType;
pointType point1, point2;
```

- This is equivalent to: `struct point point1, point2;`

Operations on Structures

- Structures may be copied by assignment statement
- The address of the structure (use &) can be passed to functions and can be returned by functions
  - one can pass an entire structure
  - one can pass some components of a structure
  - one can pass a pointer to a structure
- Structures may not be compared

Functions and Structures

- Structure as function argument

```
int isOrigin(pointType pt){
    if (pt.x == 0 && pt.y == 0)
        return 1;
    else
        return 0;
}
```


Structures and Functions

- Structure as return type

```
pointType makePoint(int x, int y){
    pointType temp;
    temp.x = x;
    temp.y = y;
    return temp;
}
```

Observe there is no confusion between the two occurrences of *x* and *y*

A Screen and its Centre Point

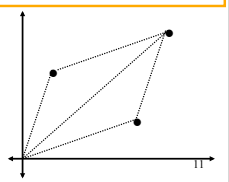
```
struct rectangle screen;
struct point middle;
struct point makePoint(int, int);

screen.pt1 = makePoint(0, 0);
screen.pt2 = makePoint(XMAX, YMAX);
middle =
    makePoint((screen.pt1.x+screen.pt2.x)/2,
              (screen.pt1.y+screen.pt2.y)/2);
```


Adding Two Points

```
/* addPoints: add two points */
struct point addPoints(struct point p1, struct point p2)
{   p1.x += p2.x;
    p1.y += p2.y;
    return p1;}
```

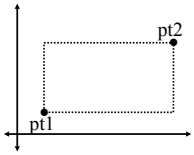
Note that the local changes to p1 would not affect the point p1; *pass by value*



Point Inside a Rectangle?

- /* isPtInRect: return 1 if point p is in rectangle r, else return 0 */

```
int isPtInRect(struct point p, struct rectangle r){
  return (p.x >= r.pt1.x) && (p.x < r.pt2.x) &&
         (p.y >= r.pt1.y) && (p.y < r.pt2.y);
}
```



A Canonical Rectangle

```
#define min(a, b) ((a<b)?a:b)  /*Macro definitions*/
#define max(a, b) ((a>b)?a:b)
struct rectangle canonRect(struct rect r){
            /*canonicalize coordinates of rectangle*/
   struct rectangle temp;
   temp.pt1.x = min(r.pt1.x, r.pt2.x);
   temp.pt1.y = min(r.pt1.y, r.pt2.y);
   temp.pt2.x = max(r.pt1.x, r.pt2.x);
   temp.pt2.y = max(r.pt1.y, r.pt2.y);
   return temp;
}
```


Arrays of Structures

```
struct point{
    int x;
    int y;
    }pointArray[10];
```

```
struct point {
    int x;
    int y;
    }pointArray[ ] = {
        {1, 2},
        {2, 3},
        {3, 4}
    };
```

```
pointType pointArray[10];
```


Accessing Member Values

- Assigning values to structure elements

```
pointArray[0].x = 1;
pointArray[0].y = 2;
```

OR

```
pointArray[i].x = 5;
pointArray[i].y = 5;
```

- Printing elements of Structures

```
printf("(%d,%d)", pointArray[0].x,
                   pointArray[0].y);
```


Structure1 = Structure2

- Structures can be assigned using the assignment operator

```
struct point newPoint;
newPoint = makePoint(4,4);
```


Example Structure Definition

```
typedef struct student{
        char name[30];
        int rollNo;
        char gender;
        char hostel[8];
        int roomNo;
    }StudentType;
```

Components can be of any type - even struct

Observe the semi-colons

Creates - a new data type called *StudentType*
a composite type with 5 components

Can be used in type declarations of variables

```
StudentType jayanthi, vikas, mahesh;
```


Another Definition

```
typedef struct book{
        char title[20];
        char authors[30];
        int accNo;
        char subject[25];
    }BookType;
BookType cText;          // a C textbook
BookType shelf[100];     // a shelf holds 100 books
```

Using Structures

- Let us create a type for complex numbers and a few operations on complex numbers

```
typedef struct {
        float real;
        float imag;
}Complex;
Complex sum (Complex m, Complex n);
Complex product (Complex m, Complex n);
```


Using Complex Type

Dot (.) Notation: Accessing components of a structure

```
main( ){
        Complex a,b,c,d;
        scanf("%f %f", &a.real, &a.imag);
        scanf("%f %f", &b.real, &b.imag);
        c = sum(a,b);
        d = product(a,b);
        printf("Sum of a and b is %f +i%f\n", c.real,
                                                c.imag);
        printf("Product of a and b is %f+i%f\n",
                                        d.real, d.imag);
}
```


Sum and Product

```
Complex Sum(Complex m, Complex n){
   Complex p;
   p.real = m.real + n.real;   p.imag = m.imag + n.imag;
   return (p);
}
```

```
Complex Product(Complex m, Complex n){
   Complex p;
   p.real = (m.real * n.real) – (m.imag * n.imag);
   p.imag = (m.real * n.imag) + (m.imag * n.real);
   return (p);
}
```


Pointers to Structures

```
pointType  point1, *ptr;

point1 = makePoint(3,4);
ptr = &point1;
printf("(%d,%d)",(*ptr).x,(*ptr).y);
     OR
printf("(%d,%d)",ptr->x,ptr->y);
```

The brackets are necessary. Otherwise it is taken as *(ptr.x)

equivalent short form

- The operator '->'(minus sign followed by greater than symbol) is used to access members of structures when pointers are used.

Precedence and Association

- Both . and -> associate left to right
  - They are at top of precedence hierarchy
- If we have
  - `struct rectangle r, *rp = r;`
  - The following forms are equivalent

    r.pt1.x (r.pt1).x

    rp -> pt1.x (rp -> pt1).x

    (*rp).pt1.x

Recall: Precedence & Associativity of Operators

Operators	Associativity
() [] -> .	left to right
! ~ ++ -- + - * (type) sizeof	right to left
* / %	left to right
+ -	left to right
<< >>	left to right
< <= > >=	left to right
== !=	left to right
&	left to right
^	left to right
|	left to right
&&	left to right
||	left to right
?:	right to left
= += -= *= /= %= &= ^= |= <<= >>=	right to left
,	left to right

Bitwise operators

Table from K & R book 2nd edn. page 53

More Examples

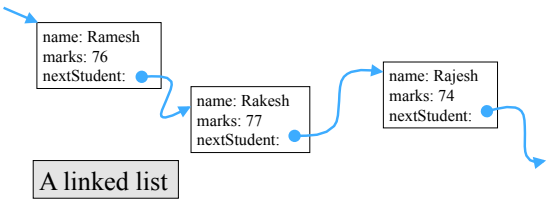
- Given the declaration ***struct***{***int*** *len*;***char*** **str*;} **p*;
- ++*p*-> *len* // increments *len* not *p*; same as ++(*p*-> *len*)
- (++*p*)-> *len* // increments *p* before accessing *len*
- *p*++-> *len* // increments *p* after accessing *len*
- **p*->*str* // fetches whatever *str* points to
- **p*->*str*++ // increments *str* after accessing // whatever it points to
- (*p->str)++ // increments whatever *str* points to
- **p*++-> *str* // increments *p* after accessing whatever *str* // points to

Dynamic Data Structures

- How does one cater to an uncertain and changing amount of memory requirements?
  - for example if the number of students writing an online surprise exam is unknown
- One way is to use dynamic tables/arrays
  - declare an array of some size N
  - if it seems to be getting full declare an array of twice the size and copy all elements into it
- The other is to ask for memory for a structure one at a time and link them together

Self Referential Structures

- The structure contains a pointer to a structure of the same type
  - this is in addition to the other data it stores
  - let student contain name and marks



A linked list

Creating a List of Words and Frequencies (1/2)

We create a linked list of 10 words, read from input and set their frequencies as 1. We go down the list to also print the words.

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
typedef struct node
   {char word[20]; int freq; struct node *nextWord;} wordNode;
void main( ) {
  wordNode *firstNode, *temp, *lastNode;
  firstNode = NULL;
  for (int i = 0; i < 10; i++) { /* create a 10 word list with freq = 1 */
    char word[20];
    printf ("Input a word of max length 20 and press enter: ");
    scanf ("%s", word);
```


Creating a List of Words and Frequencies (2/2)

```
    temp = (wordNode *) malloc (sizeof(wordNode));
    strcpy(temp->word, word); temp->freq = 1;
    if (firstNode == NULL) firstNode = temp;  /* add the new node*/
      else lastNode -> nextWord = temp;
    lastNode = temp; } /* end of for loop */
Temp =  firstNode;
Printf ("The words you gave are: \n");
While (temp != NULL) do {
Printf ("%s \n", temp->word);
Temp = temp->nextWord; }
} /* end of main */
```


Exercise

- Suppose we have a travel agency which stores information about each flight:
  - Flight Number
  - Originating airport code (3 letters)
  - Destination airport code (3 letters)
  - Departure Time
  - Arrival Time
- Define a structure(s) for the flight information
- Write a function to read in the flight info for all flights
- Write a function to find the info for a given origin and destination

Solution: FlightInfo Structure

- We will start with a structure which represents flight information

```
struct FlightInfo{
        String flightNo;
        String origin;
        String destination;
        Time  depTime;
        Time  arrTime;
};
```


String and Time Types

- But 'C' does not have any 'String' or 'Time' data types.
  - We can define them!

```
typedef char* String;
```
//Don't forget to allocate memory using malloc!!!

OR

```
typedef char[10] String;
```
//But this will allocate more memory than actually required

```
struct TimeData
{
    int hour;
    int minute;
};
typedef struct TimeData Time;
```


Reading In the Data

```
struct FlightInfo agency1[MAX_FLIGHTS];
void ReadInfo(int numFlights, struct FlightInfo flightList[ ]){
        for (i=1; i< numFlights; i++){
                printf("Enter Flight Number %d", i);
                scanf(" %s", flightList[i].flightNo);
                printf("Enter Origin (3 letter code): ");
                scanf(" %s", flightList[i].origin);
                printf("Enter Destination(3 letter code): ");
                scanf(" %s", flightList[i].destination);
                printf("Enter Departure Time (hh:mm): ");
                scanf(" %d%d", &flightList[i].depTime.hour,
                                        &flightList[i].depTime.minute);
                printf("Enter Arrival Time (hh:mm): ");
                scanf(" %d%d", &flightList[i].arrTime.hour,
                                        &flightList[i].arrTime.minute);
        }}
```



```
void RetrieveFlight(struct FlightInfo flightList[], int numFlights){
    String userOrigin, userDest;
    printf ("\nEnter the origin and destination airport codes: ");
    scanf (" %s, %s", userOrigin, userDest);

    for (int i=0;  i < numFlights; i++) {
     if  ((strcmp(flightList[i].origin, userOrigin) == 0) &&
          (strcmp(flightList[i].destination, userDest) == 0)) {
         printf("\nFlight Number: %s \n", flightList[i].flightNo);
         printf("Departure Time: %d: %d\n",
             flightList[i].depTime.hour,  flightList[i].depTime.minute );
         printf("Arrival Time: %d: %d \n",
             flightList[i]. arrTime.hour,  flightList[i].arrTime.minute );
    }
}
```


Storing and Accessing Elements

- Linked list are accessed by following the pointers
  - linear time complexity
- Search trees are traversed by comparing values at nodes
  - logarithmic time complexity for balanced trees
- Array elements are accessed by using the index
  - constant time complexity
  - index value should be known (else search)
- Can we store names/strings in arrays?
  - and find them in constant time
  - Yes, in Hash tables (average complexity)

Computer Solutions

- Problem Solving
  - main purpose of using computers
- Steps
  - clear specification, understanding of the problem
  - remove unnecessary details and retain only the required parameters, constraints of the problem
    - "abstraction" - better insight, helps in thinking
  - find the method of solving the problem
    - "algorithm design" - "efficiency"
  - express the solution in a programming language

References

- Peter Grogono and Sharon Nelson, Problem Solving and Computer Programming, Narosa, 1987.
- R G Dromey, How to Solve it by Computer, Prentice-Hall India, 1996.

Homework Exercise

- Write a program to take a filename as a command line argument, open the file and count the frequencies of the different words in the file.
- Given a "-n" option it should print the words preceded by their counts in an increasing order of frequency, one word per line.
- Otherwise it should print the words in alphabetic order