STRUCTURES

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Introduction

Structures

- Collections of related variables (aggregates) under one name
  - Can contain variables of different data types
- Commonly used to define records to be stored in files
- Combined with pointers, can create linked lists, stacks, queues, and trees

Structure Definitions

Example 1:

```
struct card {
    char *face;
    char *suit;
 };
```

- `struct` introduces the definition for structure `card`
- `card` is the structure name and is used to declare variables of the structure type
- `card` contains two members of type `char *`
  - These members are `face` and `suit`

Structure Definitions

- A structure definition does not reserve space in memory
  - Instead creates a new data type used to define structure variables

- Variables can be defined as below:

```
struct card {
   char *face;
   char *suit;
} oneCard, deck[ 52 ], *cPtr;
```

- Or defined like other variables:

```
struct card {
   char *face;
   char *suit;
};
struct card oneCard, deck[ 52 ], *cPtr;
```

Structure Definitions

Example 2:

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

struct point pt; /* defines a variable pt which
                    is a structure of type
                    struct point */

pt.x = 15;
pt.y = 30;
printf(“%d, %d”, pt.x, pt.y);
```

Structure Definitions

```
/* Structures can be nested.  One representation of
 a  rectangle is a pair of points that denote the
 diagonally opposite corners. */

struct rect {
     struct point pt1;
     struct point pt2;
};

struct rect screen;

/* Print the pt1 field of screen */
printf("%d, %d",screen.pt1.x,screen.pt1.y);

/* Print the pt2 field of screen */
printf("%d, %d",screen.pt2.x,screen.pt2.y);
```

Structure Definitions

Valid Operations

- Assigning a structure to a structure of the same type
- Taking the address (&) of a structure
- Accessing the members of a structure
- Using the sizeof operator to determine the size of a structure

Initializing Structures

- Initializer lists
  - Example:

    card oneCard = { "Three", "Hearts" };

- Assignment statements
  - Example:

    card threeHearts = oneCard;

  - Could also define and initialize threeHearts as follows:

    card threeHearts;

    threeHearts.face = “Three”;

    threeHearts.suit = “Hearts”;

Accessing Members of Structures

- Accessing structure members
  - Dot operator (`.`) used with structure variables

```
card myCard;
printf( "%s", myCard.suit );
```

  - Arrow operator (`->`) used with pointers to structure variables

```
card *myCardPtr = &myCard;
printf( "%s", myCardPtr->suit );
```

  - `myCardPtr->suit` is equivalent to

```
( *myCardPtr ).suit
```

```c
#include <stdio.h>

/* card structure definition */
struct card {
   char *face; /* define pointer face */
   char *suit; /* define pointer suit */
}; /* end structure card */

int main() {
       struct card a;     /* define struct a */
       struct card *aPtr; /* define a pointer to card */

        a.face = "Ace";
        a.suit = "Spades";
        aPtr = &a; /* assign address of a to aPtr */

        printf( "%s of %s\n", a.face, a.suit);
        printf( "%s of %s\n", aPtr->face, aPtr->suit);
        printf( "%s of %s\n", ( *aPtr ).face, ( *aPtr ).suit);

        return 0; /* indicates successful termination */
} /* end main */
```

Program Output :

```
Ace of Spades
Ace of Spades
Ace of Spades
```

typedef

typedef

- Creates synonyms (aliases) for previously defined data types
- Use **typedef** to create shorter type names

Example:

typedef struct point pixel;

- Defines a new type name **pixel** as a synonym for type **struct point**

typedef struct Card *CardPtr;

- Defines a new type name **CardPtr** as a synonym for type **struct Card ***

- **typedef** does not create a new data type
  - Only creates an alias

Using Structures With Functions

- Passing structures to functions
  - Pass entire structure
    - Or, pass individual members
  - Both pass call by value

- To pass structures call-by-reference
  - Pass its address
  - Pass reference to it

- To pass arrays call-by-value
  - Create a structure with the array as a member
  - Pass the structure

Using Structures with Functions 1

```
#include<stdio.h> /* Demonstrates passing a structure to a
  function */

struct data{
    int amount;
    char fname[30];
    char lname[30];
}rec;

void printRecord(struct data x){
   printf(“\nDonor %s %s gave $%d”, x.fname, x.lname, x.amount);
}

int main(void){
      printf(“Enter the donor’s first and last names\n”);
      printf(“separated by a space:  ”);
      scanf(“%s %s”,rec.fname, rec.lname);
      printf(“Enter the donation amount:   ”);
      scanf(“%d”,&rec.amount);
      printRecord(rec);
      return 0;
}
```

Using Structures with Functions 2

```
/* Make a point from x and y components. */
struct point makepoint (int x, int y)
{
       struct point temp;

       temp.x = x;
       temp.y = y;
       return (temp);

}

/* makepoint can now be used to initialize a structure */
struct rect screen;
struct point middle;

screen.pt1 = makepoint(0,0);
screen.pt2 = makepoint(50,100);
middle = makepoint((screen.pt1.x + screen.pt2.x)/2,
                   (screen.pt1.y + screen.pt2.y)/2);
```

```
/* add two points */

struct point addpoint (struct point p1, struct point p2)
{
     p1.x += p2.x;
     p1.y += p2.y;
     return p1;
}
```

Both arguments and the return value are structures in the function addpoint.

Structures and Pointers

```
struct point *p;  /* p is a pointer to a structure
                     of type struct point */
struct point origin;

p = &origin;
printf("Origin is (%d, %d)\n", (*p).x, (*p).y);
```

- Parenthesis are necessary in `(*p).x` because the precedence of the structure member operator (dot) is higher than *.
- The expression `*p.x` ≡ `*(p.x)` which is illegal because x is not a pointer.

Structures and Pointers

- Pointers to structures are so frequently used that an alternative is provided as a shorthand.
- If p is a pointer to a structure, then

```
p -> field_of_structure
```

refers to a particular field.

- We could write

```
printf("Origin is (%d %d)\n", p->x, p->y);
```

Assignments

```
struct student {
        char *last_name;
        int student_id;
        char grade;
};
struct student temp, *p = &temp;

temp.grade = ‘A’;
temp.last_name = “Casanova”;
temp.student_id = 590017;
```

Expression	**Equiv. Expression**	**Value**
temp.grade	p -> grade	A
temp.last_name	p -> last_name	Casanova
temp.student_id	p -> student_id	590017
(*p).student_id	p -> student_id	590017

Structures and Pointers

- Both `.` and **`->`** associate from left to right
- Consider

```
struct rect r, *rp = &r;
```

- The following 4 expressions are equivalent.

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

```
struct rect {
    struct point pt1;
    struct point pt2;
};
```

Arrays of Structures

- Usually a program needs to work with more than one instance of data.
- For example, to maintain a list of phone #s in a program, you can define a structure to hold each person's name and number.

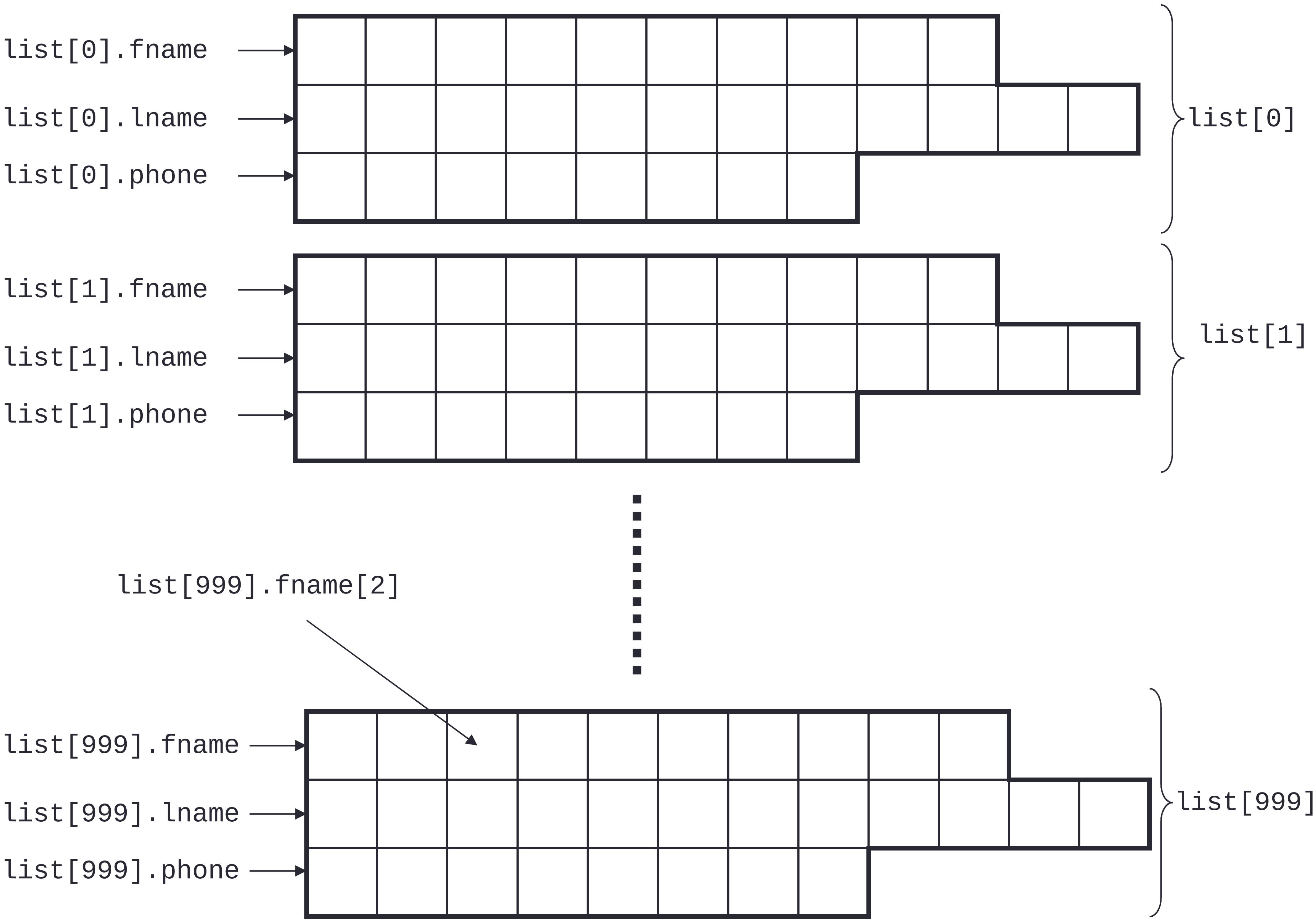
```
struct entry {
    char fname[10];
    char lname[12];
    char phone[8];
};
```

Arrays of Structures

- A phone list has to hold many entries, so a single instance of the entry structure isn't of much use. What we need is an array of structures of type entry.
- After the structure has been defined, you can define the array as follows:

```
struct entry list[1000];
```

struct entry list[1000]



- To assign data in one element to another array element, you write

```
list[1] = list[5];
```

- To move data between individual structure fields, you write

```
strcpy(list[1].phone, list[5].phone);
```

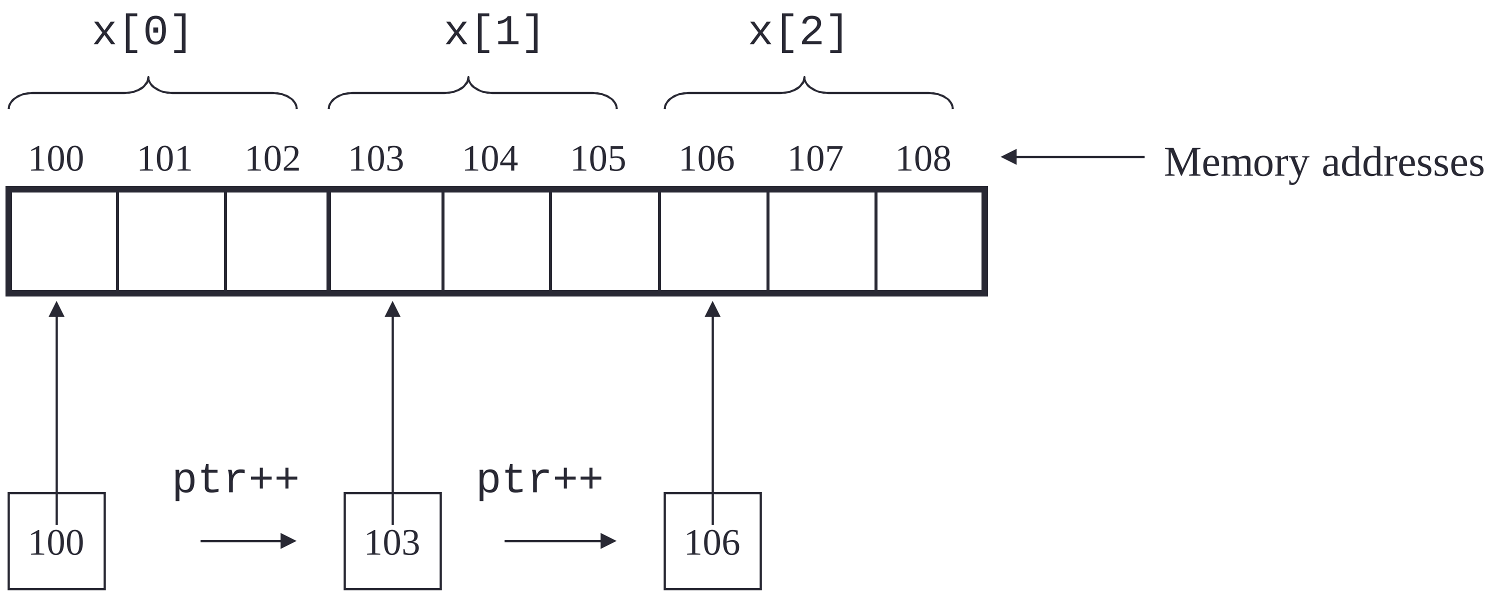
- To move data between individual elements of structure field arrays, you write

```
list[5].phone[1] = list[2].phone[3];
```

```
#define CLASS_SIZE 100
struct student {
        char *last_name;
        int student_id;
        char grade;
};

int main(void)
{
        struct student temp,
                class[CLASS_SIZE];

        ... /*Do some operation to fill class structure*/

        printf (“Number of A’s in class: %d\n”, countA(class));
}

int countA(struct student class[])
{
        int i, cnt = 0;
        for (i = 0; i < CLASS_SIZE; ++i)
                cnt += class[i].grade == ‘A’;
        return cnt;
}
```

• Arrays of structures can be very powerful programming tools, as can pointers to structures.

```
struct part {
        int number;
        char name [10];
};

struct part data[100];
struct part *p_part;

p_part = data;
printf(“%d %s”, p_part->number, p_part -> name);
```



- The above diagram shows an array named *x* that consists of 3 elements. The pointer *ptr* was initialized to point at x[0]. Each time *ptr* is incremented, it points at the next array element.

```
/* Array of structures */
#include <stdio.h>
#define MAX 4

struct part {
        int number;
        char name[10];
};

struct part data[MAX]= {1, “Smith”, 2, “Jones”, 3, “Adams”, 4, “Will”};

int main (void)
{
        struct part *p_part;
        int count;

        p_part = data;
        for (count = 0; count < MAX; count++) {
           printf(“\n %d %s”, p_part -> number, p_part -> name);
           p_part++;
        }
        return 0;
}
```

Unions

- `union`
  - Memory that contains a variety of objects over time
  - Only contains one data member at a time
  - Members of a `union` share space
  - Conserves storage
  - Only the last data member defined can be accessed

- `union` definitions
  - Same as struct

```
union Number {
  int x;
  float y;
};
union Number value;
```

Unions

- Valid `union` operations
  - Assignment to `union` of same type: `=`
  - Taking address: `&`
  - Accessing union members: `.`
  - Accessing members using pointers: `->`

```
/* number union definition */
union number {
       int x;    /* define int x */
       double y; /* define double y */
}; /* end union number */

int main(){
        union number value; /* define union value */

        value.x = 100; /* put an integer into the union */

        printf("Put a value in the integer member.\n");
         printf(" int: %d\n double:%f\n\n", value.x, value.y );

         value.y = 100.0; /* put a double into the same union */

         printf("Put a value in the floating member.\n");
         printf(" int: %d\n double:%f\n\n", value.x, value.y );

         return 0; /* indicates successful termination */
} /* end main */
```

```
Put a value in the integer member.
int:   100
double:-
925595921174331360000000000000000000000000000000
00000000000000.000000

Put a value in the floating member.
int:   0
double: 100.000000
```

Enumeration Constants

- Enumeration
  - Set of integer constants represented by identifiers
  - Enumeration constants are like symbolic constants whose values are automatically set
    - Values start at 0 and are incremented by 1
    - Values can be set explicitly with =
    - Need unique constant names

  - Example:

```
enum Months { JAN = 1, FEB, MAR, APR, MAY, JUN, JUL, AUG,
  SEP, OCT, NOV, DEC};
```

    - Creates a new type `enum` Months in which the identifiers are set to the integers 1 to 12

```
#include <stdio.h>

/* enumeration constants represent months of the year */
enum months { JAN = 1, FEB, MAR, APR, MAY, JUN,
                  JUL, AUG, SEP, OCT, NOV, DEC };

int main()
{
      enum months month; /* can contain any of the 12 months */

      const char *monthName[] = { "", "January", "February", "March",
        "April", "May", "June", "July", "August", "September", "October",
        "November", "December" };

      for ( month = JAN; month <= DEC; month++ )
        printf( "%2d %11s\n", month, monthName[ month ] );

       return 0; /* indicates successful termination */
} /* end main */
```

1	January
2	February
3	March
4	April
5	May
6	June
7	July
8	August
9	September
10	October
11	November
12	December

DATA STRUCTURES: LINKED LISTS

Introduction

- Dynamic data structures
  - Data structures that grow and shrink during execution
- Linked lists
  - Allow insertions and removals anywhere
- Stacks
  - Allow insertions and removals only at top of stack
- Queues
  - Allow insertions at the back and removals from the front
- Binary trees
  - High-speed searching and sorting of data and efficient elimination of duplicate data items

Self-Referential Structures

- Self-referential structures
  - Structure that contains a pointer to a structure of the same type
  - Can be linked together to form useful data structures such as lists, queues, stacks and trees
  - Terminated with a `NULL` pointer (**`0`**)

```
struct node {
   int data;
   struct node *nextPtr;
}
```

- `nextPtr`
  - Points to an object of type node
  - Referred to as a link
    - Ties one node to another **node**

Dynamic Memory Allocation

Two self-referential structures linked together

Dynamic Memory Allocation

- Dynamic memory allocation
  - Obtain and release memory during execution
- `malloc`
  - Takes number of bytes to allocate
    - Use `sizeof` to determine the size of an object
  - Returns pointer of type `void *`
    - A `void *` pointer may be assigned to any pointer
    - If no memory available, returns `NULL`
  - Example

```
newPtr = malloc( sizeof( struct node ) );
```

- `free`
  - Deallocates memory allocated by `malloc`
  - Takes a pointer as an argument
  - `free ( newPtr );`

Linked Lists

- Linked list
  - Linear collection of self-referential class objects, called nodes
  - Connected by pointer links
  - Accessed via a pointer to the first node of the list
  - Subsequent nodes are accessed via the link-pointer member of the current node
  - Link pointer in the last node is set to `NULL` to mark the list's end

- Use a linked list instead of an array when
  - You have an unpredictable number of data elements
  - Your list needs to be sorted quickly

Linked Lists

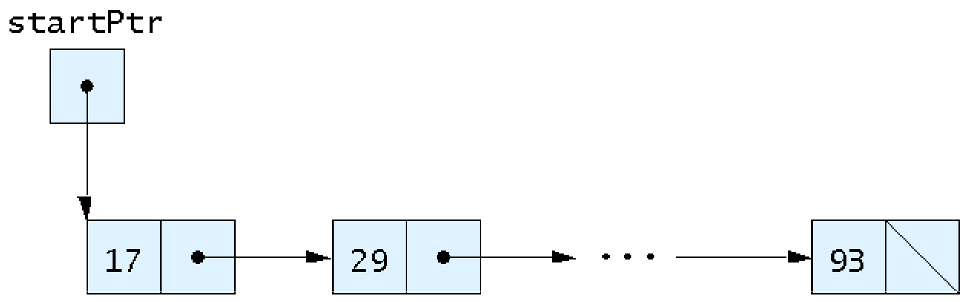


Fig. 12.2 A graphical representation of a linked list.