
- Review

- Pointers

- Void pointers
- Function pointers

- Hash table

Review:Pointers

- pointers: `int x; int* p=&x;`
- pointers to pointer: `int x; int* p=&x;int** pp=&p;`
- Array of pointers: `char* names[]={ "abba ", "u2 "};`
- Multidimensional arrays: `int x [20][20];`

Review: Stacks

- LIFO: last in first out data structure.
- items are inserted and removed from the same end.
- operations: `push()`, `pop()`, `top()`
- can be implemented using arrays, linked list

Review: Queues

- FIFO: first in first out
- items are inserted at the rear and removed from the front.
- operations: `queue()`, `dequeue()`
- can be implemented using arrays, linked list

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Void pointers

- C does not allow us to declare and use void **variables**.
- void can be used only as return type or parameter of a function.
- C allows void **pointers**
- Question: What are some scenarios where you want to pass void pointers?
- void pointers can be used to point to any data type
 - `int x; void* p=&x; /*points to int*/`
 - `float f; void* p=&f; /*points to float*/`
- void pointers cannot be dereferenced. The pointers should always be cast before dereferencing.
`void* p; printf ("%d",*p); /*invalid*/`
`void* p; int *px=(int*)p; printf ("%d",*px); /*valid*/`

Function pointers

- In some programming languages, functions are first class variables (can be passed to functions, returned from functions etc.).
- In C, function itself is not a variable. But it is possible to declare pointer to functions.
- Question: What are some scenarios where you want to pass pointers to functions?
- Declaration examples:
 - `int (*fp)(int) /*notice the ()*/`
 - `int (*fp)(void*,void*)`
- Function pointers can be assigned, pass to and from functions, placed in arrays etc.

Callbacks

Definition: Callback is a piece of executable code passed to functions. In C, callbacks are implemented by passing function pointers.

Example:

```
void qsort(void* arr, int num, int size, int (*fp)(void* pa, void*pb))
```

- `qsort()` function from the standard library can be sort an array of any datatype.
- Question: How does it do that? callbacks.
- `qsort()` calls a function whenever a comparison needs to be done.
- The function takes two arguments and returns ($<0, 0, >0$) depending on the relative order of the two items.

Callback (cont.)

```
int arr[]={10,9,8,1,2,3,5};
/* callback */
int asc(void* pa, void* pb)
{
    return (* (int*)pa - *(int*)pb);
}
/* callback */
int desc(void* pa, void* pb)
{
    return (* (int*)pb - *(int*)pa);
}
/* sort in ascending order */
qsort(arr, sizeof(arr)/sizeof(int), sizeof(int), asc);
/* sort in descending order */
qsort(arr, sizeof(arr)/sizeof(int), sizeof(int), desc);
```

Callback (cont.)

Consider a linked list with nodes defined as follows:

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

Also consider the function 'apply' defined as follows:

```
void apply(struct node* phead,  
          void (*fp)(void*,void* ),  
          void* arg) /* only fp has to be named */  
{  
    struct node* p=phead;  
    while (p!=NULL)  
    {  
        fp(p, arg); /* can also use (*fp)(p, arg) */  
        p=p->next;  
    }  
}
```

Callback (cont.)

Iterating:

```
struct node* phead;  
/* populate somewhere */  
void print(void* p, void* arg)  
{  
    struct node* np=(struct node*)p;  
    printf("%d ", np->data);  
}  
apply(phead, print, NULL);
```

Callback (cont.)

Counting nodes:

```
void dototal(void* p, void* arg)
{
    struct node* np=(struct node*)p;
    int* ptotal      =(int*)arg;
    *ptotal += np->data;
}
int total=0;
apply(phead, dototal, &total);
```

Array of function pointers

Example: Consider the case where different functions are called based on a value.

```
enum TYPE{SQUARE,RECT,CIRCILE ,POLYGON};
struct shape{
    float params[MAX];
    enum TYPE type;
};
void draw(struct shape* ps)
{
    switch(ps->type)
    {
        case SQUARE:
            draw_square(ps); break;
        case RECT:
            draw_rect(ps); break;
        ...
    }
}
```

Array of function pointers

The same can be done using an array of function pointers instead.

```
void (*fp[4])(struct shape* ps)=
{&draw_square,&draw_rec,&draw_circle,&draw_poly};
typedef void (*fp)(struct shape* ps) drawfn;
drawfn fp[4]=
{&draw_square,&draw_rec,&draw_circle,&draw_poly};
void draw(struct shape* ps)
{
    (*fp[ps->type])(ps); /* call the correct function */
}
```

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Hash table

Hash tables (hashmaps) combine linked list and arrays to provide an *efficient* data structure for storing dynamic data. Hash tables are commonly implemented as an array of linked lists (hash tables with chaining).

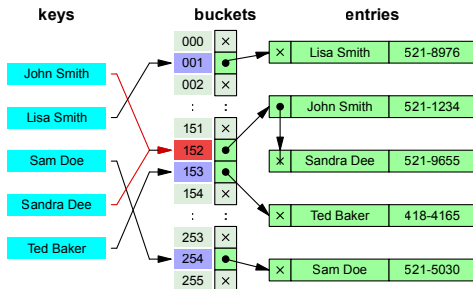


Figure: Example of a hash table with chaining (source: wikipedia)

Hash table

- Each data item is associated with a *key* that determines its location.
- *Hash functions* are used to generate an evenly distributed hash value.
- A *hash collision* is said to occur when two items have the same hash value.
- Items with the same hash keys are chained
- Retrieving an item is $O(1)$ operation.

Hash tables

Hash functions:

- A hash function maps its input into a finite range: hash value, hash code.
- The hash value should ideally have uniform distribution. why?
- Other uses of hash functions: cryptography, caches (computers/internet), bloom filters etc.
- Hash function types:
 - Division type
 - Multiplication type
- Other ways to avoid collision: linear probing, double hashing.

Hash table: example

```
#define MAX_BUCKETS 1000
#define MULTIPLIER 31
struct wordrec
{
    char* word;
    unsigned long count;
    struct wordrec* next;
};

/* hash bucket */
struct wordrec* table[MAX_LEN];
```

Hash table: example

```
unsigned long hashstring(const char* str)
{
    unsigned long hash=0;
    while(*str)
    {
        hash= hash*MULTIPLIER+*str;
        str++;
    }
    return hash%MAX_BUCKETS;
}
```

Hash table: example

```
struct wordrec* lookup(const char* str, int create)
{
    struct wordrec* curr=NULL;
    unsigned long hash=hashstring(str);
    struct wordrec* wp=table[hash];
    for(curr=wp; curr!=NULL ; curr=curr->next)
        /* search */;
    notfound:
    if(create)
        /* add to front */
    return curr;
}
```