Please tidy up your emotions.

We will be landing soon.

C语言程序设计

C Programming

17

高级数据表示

理论课程

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内容要点

- 高级数据表示
- 链表
  - 链表的建立：头插法、尾插法
  - 链表的遍历：求长度、显示
  - 链表的插入和删除
  - 链表的销毁
- 抽象数据类型

目录

1 高级数据表示

2 链表及其基本操作

3 抽象数据类型

研究数据表示

- 程序＝数据结构＋算法
  - 数据结构：程序以何种形式来存储信息

例：位图，一般采用二维数组存储其灰度（亮度）信息。为什么？

- 示例：
  - 题：某影评机构请你做一个程序，输入客户看过的电影列表，记录片名、（中间省略若干字）、您的评价等。
  - 拟采用数据结构
    - 结构体：意义不同，数据类型不同，范畴相近
    - 数组：意义相同，数据类型相同，仅有次序区别

```c
/* films1.c -- using an array of structures */
#include <stdio.h>
#include <string.h>
#define TSIZE        45     /* size of array to hold title   */
#define FMAX         5      /* maximum number of film titles */
struct film {
    char title[TSIZE];
    int rating;
};
char* s_gets(char str[], int lim);
int main(void) {
    struct film movies[FMAX];
    int i = 0;
    int j;
    puts("Enter first movie title:");
    while (i < FMAX && s_gets(movies[i].title, TSIZE) != NULL &&
           movies[i].title[0] != '\0') {
        puts("Enter your rating <0-10>:");
        scanf("%d", &movies[i++].rating);
        while (getchar() != '\n')
            continue;
```

```
            puts("Enter next movie title (empty line to stop):");
        }
        if (i == 0)
            printf("No data entered. ");
        else
            printf("Here is the movie list:\n");
        for (j = 0; j < i; j++)
            printf("Movie: %s  Rating: %d\n", movies[j].title,
                    movies[j].rating);
        printf("Bye!\n");
        return 0;
}

char* s_gets(char* st, int n) {
        char* ret_val;
        char* find;
        ret_val = fgets(st, n, stdin);
        if (ret_val) {
            find = strchr(st, '\n');   // look for newline
```

```
        if (find)           // if the address is not NULL,
            *find = '\0'; // place a null character there
        else
            while (getchar() != '\n')
                continue; // dispose of rest of line
    }
    return ret_val;
}
```

数组的局限性

- 数组的总长度应在声明时固定，不可扩充
  - 电影名总长度可调研，预先设定
  - 电影数量不可预设，用户也没法算一辈子会看几部电影
    - 万一我看了FMAX+1部电影，会引发一个运行错误

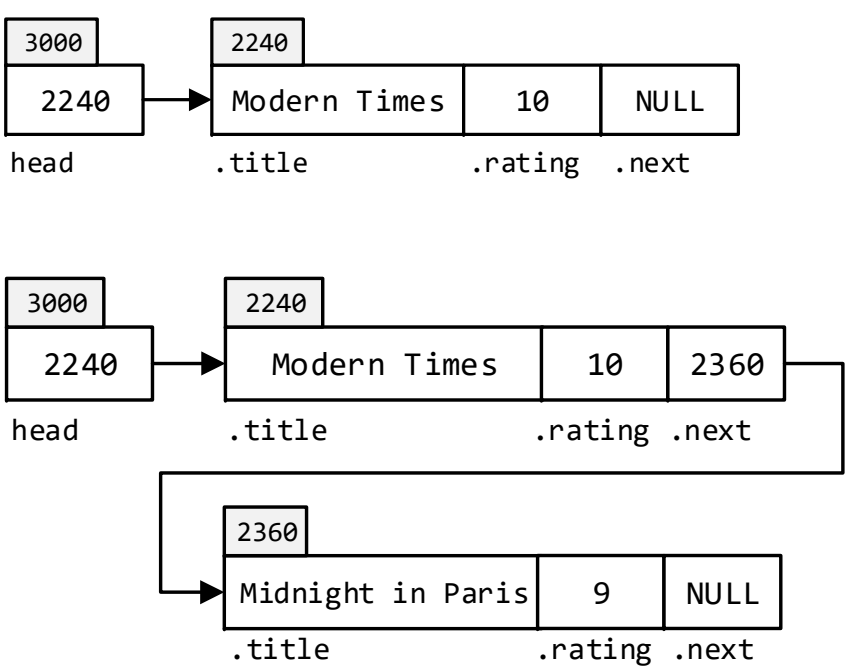
```
int n, i;
struct film* movies; /* pointer to a structure */
...
printf("Enter the maximum number of movies you'll
enter:\n");
scanf("%d", &n);
movies = (struct film*)malloc(n * sizeof(struct film));
```

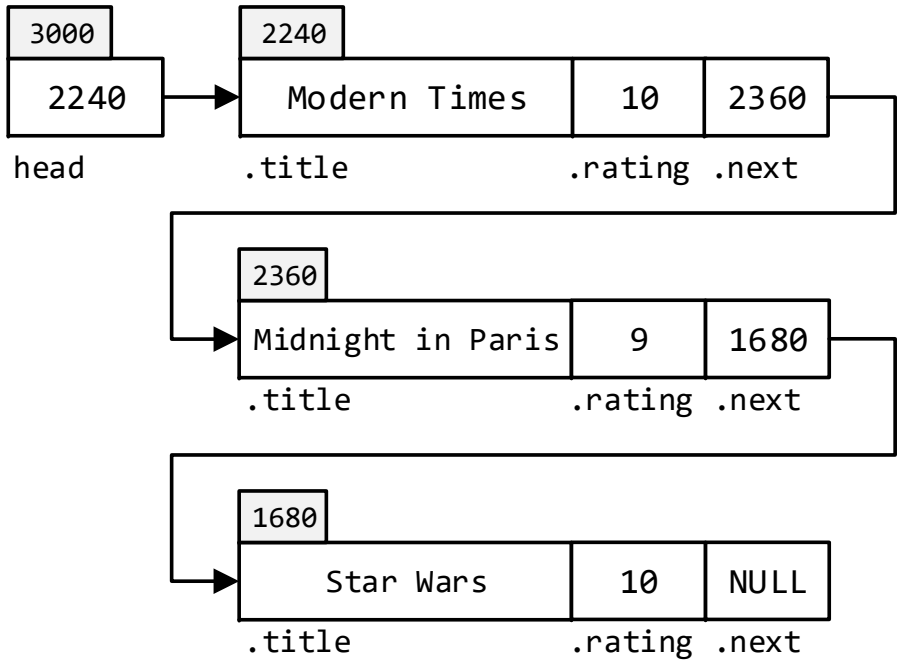
目录

1	高级数据表示
2	链表及其基本操作
3	抽象数据类型

从数组到链表

- 理想情况下，你希望不确定地添加数据
  - 依次输入多部电影，输入结束前总数未知
- 方案





链表

- 链表是在每个结点存储下一结点位置的线性表
- 物理上非顺序，逻辑上顺序
  - 数据元素的逻辑顺序是通过链表中的指针链接次序实现的。
- 组成
  - 链表由一系列结点（链表中每一个元素称为结点）组成
  - 结点可以在运行时动态生成
  - 结点包括两个部分
    - 存储数据元素的数据域
    - 存储下一个结点地址的指针域

```
struct film {
    char title[TSIZE];
    int rating;
    struct film* next;
};
```

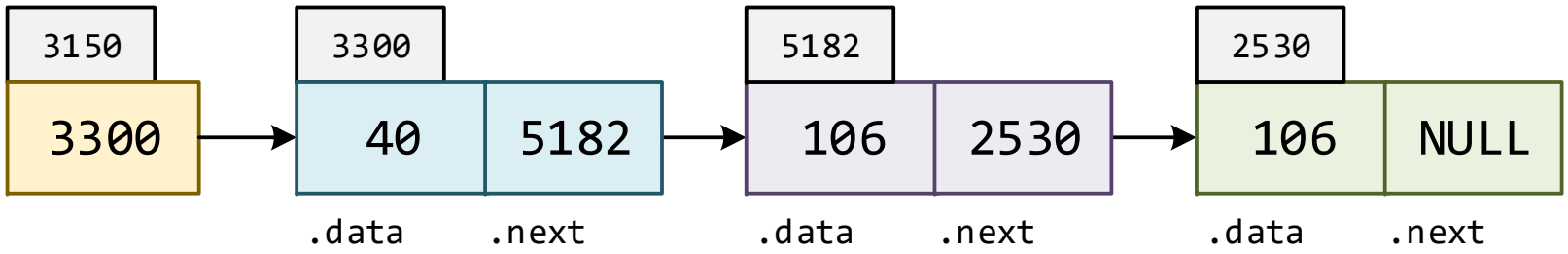
培养“读+写”的能力

- 过程
  - 读：先将代码转成图示
  - 记：通过理解记住图示
  - 写：再将图示转成代码
- 要点
  - 分清层次，一开始不要考虑太细节的问题，有计划补充

数据结构

- 结点
  - 数据（data是数据域的示例）
  - 下一结点指针 `p->next = NULL;`
- 链表
  - 链表头：指向第一个结点的指针
  - 链表中：next成员指向下一个结点
  - 链表尾：next成员置为空

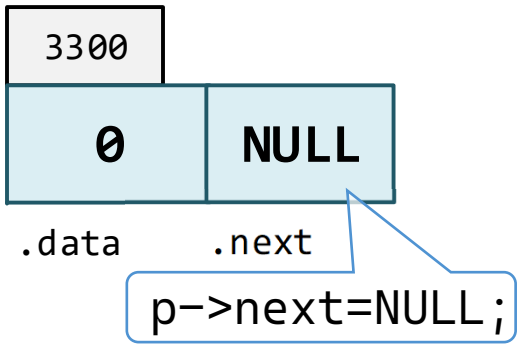
```
typedef struct node {
    int data;
    struct node * next;
} node, * linklist;
```



创建结点并链接到另一个结点

- 新建结点

```
node *p = (node*)malloc(sizeof(node));
```

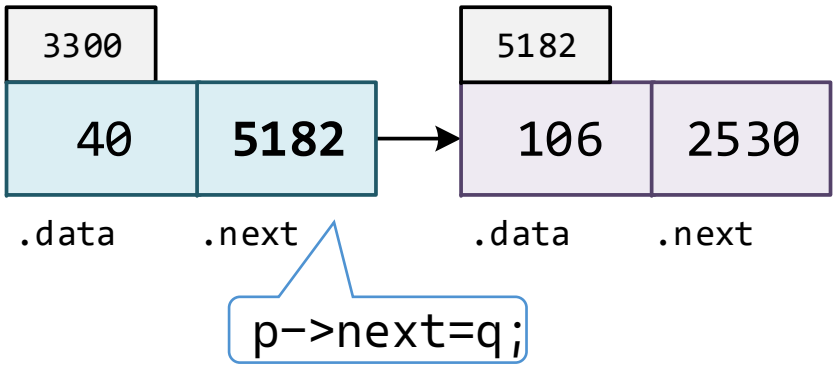


- 赋初始值
  - next初始值一般赋值为NULL
  - 成员初始值一般按惯例赋值

```
p->data = 0;
p->next = NULL;
```

- 形成前后顺序
  - next赋值为另一结点的地址

```
p->data = 40;
p->next = q;
```



创建结点并链接到另一个结点

- 完整程序

```
node* create_node() {
    node* current = (node*)malloc(sizeof(node));
    if (current == NULL) {
        fprintf(stderr, "%s\n", "Failed to allocate the
new node due to not enough memory space.");
        return NULL;
    }
    current->data = 0;
    current->next = NULL;
    return current;
}
```

创建列表：尾插法

- 示例代码

```
while (get_data_from_input(&data) == INPUT_VALID) {
    current = create_node();
    if (current == NULL)
        break;
    current->data = data;
    if (previous == NULL)
        list = current;
    else
        previous->next = current;
    previous = current;
}
```

第一层：结点相关操作
1、分配空间
2、内存耗尽处理
3、赋初值

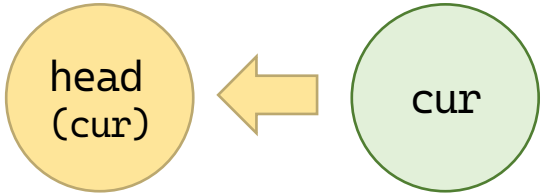
第二层：结点链接
1、list为空时，当前结点为头结点；
2、list不为空时，上一结点的后续指向当前结点；
3、记录当前结点为下次循环的前结点

创建列表：尾插法

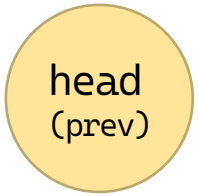
- 图示

1. head=NULL;

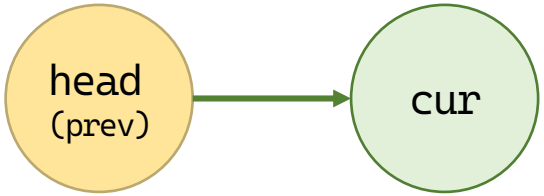
2. head=cur; //当head为NULL



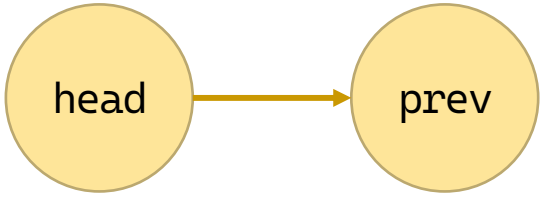
3. prev=cur;



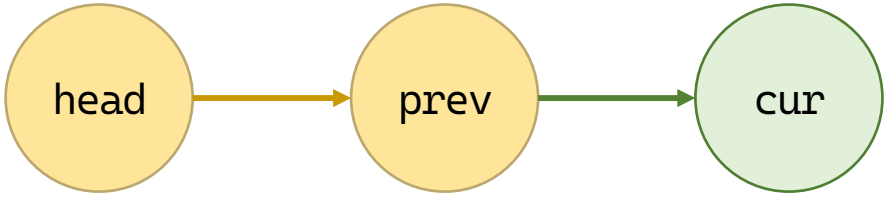
4. prev->next=cur; //当head不为NULL



5. prev=cur;



6. prev->next=cur; //当head不为NULL



创建列表：头插法

- 示例代码

```
linklist creat_from_head() {
    linklist list = NULL;
    node* current = NULL;
    int data;
    while (get_data_from_input(&data) == INPUT_VALID) {
        current = create_node();
        if (current == NULL)
            break;
        current->data = data;
        current->next = list;
        list = current;
    }
    return list;
}
```

第一层：结点相关操作
1、分配空间
2、内存耗尽处理
3、赋初值

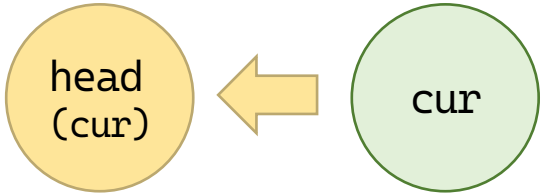
第二层：结点链接
1、当前结点的下一结点是原链表头；
2、新链表头应为新建的结点；

创建列表：头插法

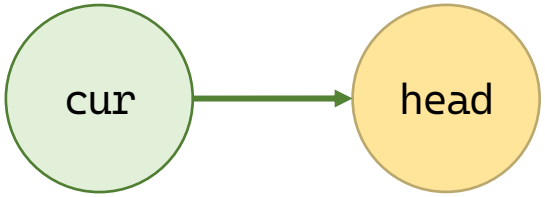
- 图示

1. head=NULL;

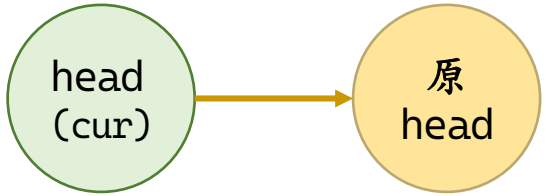
2. head=cur; //当head为NULL



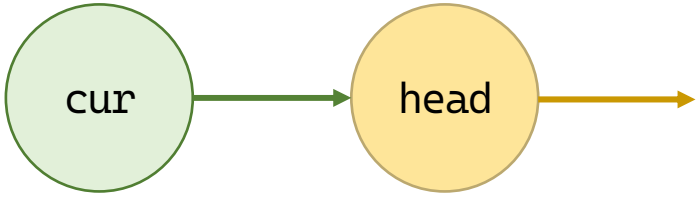
3. cur->next=head;



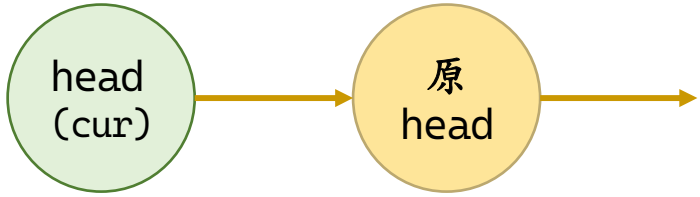
4. head=cur; //当head不为NULL



5. cur->next=head;



6. head=cur; //当head不为NULL



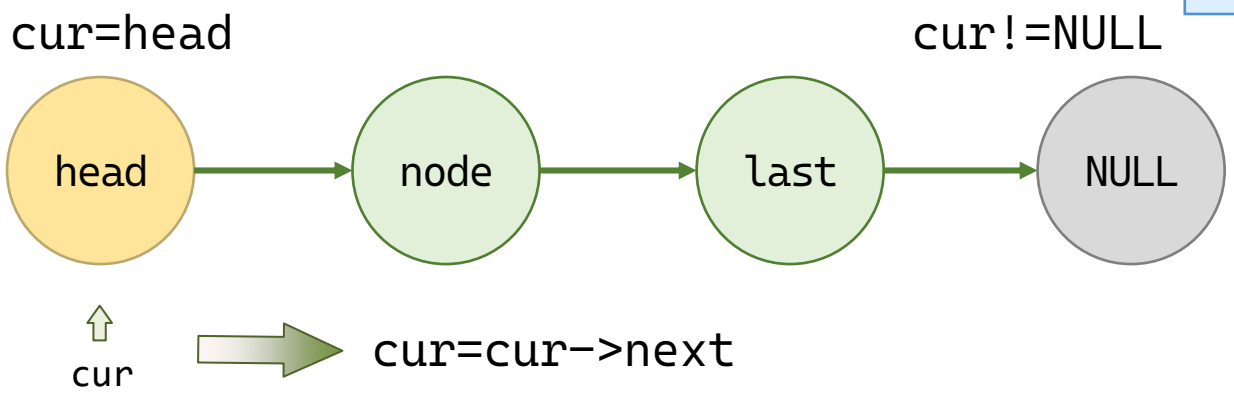
遍历链表

- 按顺序遍历数组和链表比较

功能	数组	链表
定位到第一个元素	i=0	cur=head
判断最后一个元素	i<N	cur!=NULL
移动到下一个元素	i++	cur=cur->next

```
i = 0;
while (i < N) {
    ...;
    i++;
}
```

```
cur = head;
while (cur != NULL) {
    ...;
    cur = cur->next;
}
```



计算元素个数

- 示例代码

```
size_t count(const linklist list) {
    size_t i;
    node* current = list;
    for (i = 0; current; ++i)
        current = current->next;
    return i;
}
```

计数

```
cur = head;
while (cur != NULL) {
    ++i;
    cur = cur->next;
}
```

定位元素

- 示例代码

```
node* get_item(const linklist list, const size_t offset) {
    size_t i;
    if (list == NULL) {
        fputs("Empty list.\n", stderr);
        return NULL;
    }
    node* current = list;
    for (i = 0; i < offset && current; i++)
        current = current->next;
    return current;
}
```

如果没找到，则current为NULL
不需要处理

查找元素

- 示例代码

```
node* locate(const linklist list, const int data, size_t* offset) {
    size_t i;
    if (list == NULL) {
        fputs("Empty list.\n", stderr);
        return NULL;
    }
    node* current = list;
    for (i = 0; current && current->data != data; ++i)
        current = current->next;
    if (current)
        *offset = i;
    return current;
}
```

先有cur不为空才有cur->data

如果未找到不应有副作用

显示链表

- 示例代码

```
void show(const linklist list) {
    node* current = list;
    size_t i = 0;
    if (current == NULL) {
        fputs("Empty list.\n", stderr);
        return;
    }
    printf("%-6s\t%-8s\t%-16s\t%-16s\n", "ID", "Data", "Next", "Address");
    printf("======\t========\t================\t================\n");
    while (current != NULL) {
        printf("%4zu  \t%6d  \t%016p\t%016p\n", ++i, current-
>data, current->next, current);
        current = current->next;
    }
}
```

插入元素

- 示例代码

```
int insert_item(linklist* list, const size_t offset, const int data) {
    node* previous, * current;
    size_t i;
    previous = *list;
    if (offset == 0 || *list == NULL) {
        current = create_node();
        if (current == NULL)
            return ERROR;
        current->data = data;
        current->next = *list;
        *list = current;
        return OK;
    }
```

在头插入的情况：
第一层，新建结点和初始化。

第二层：结点链接（参考头插法）
1、当前结点的下一结点是原链表头；
2、新链表头应为新建的结点；

插入元素

- 示例代码

```
    for (i = 0; i < offset - 1 && previous->next; ++i)
        previous = previous->next;
    if (i != offset - 1) {
        fputs("Failed to find the offset.", stderr);
        return ERROR;
    }
    current = create_node();
    if (current == NULL)
        return ERROR;
    current->data = data;
    current->next = previous->next;
    previous->next = current;
    return OK;
}
```

寻找插入位置的前一结点
如果不存在该位置报错

一般插入的情况：
第一层，新建结点和初始化。

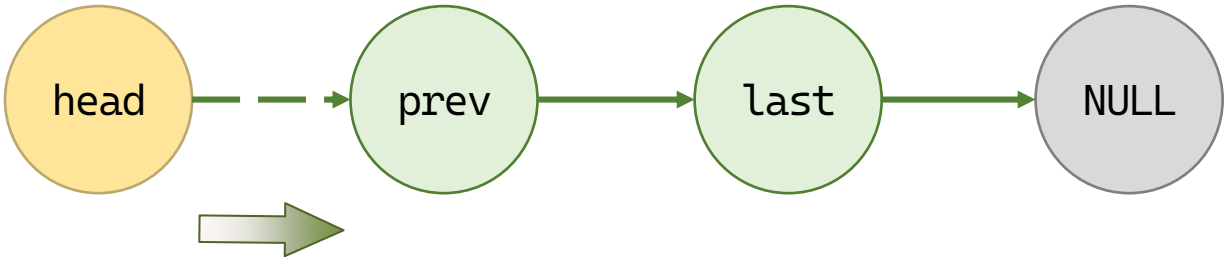
第二层：结点链接
1、新建结点的后续是前一结点的下一结点；
2、 前一结点的后续是新建结点；

插入元素

- 一般情况

1. 找prev

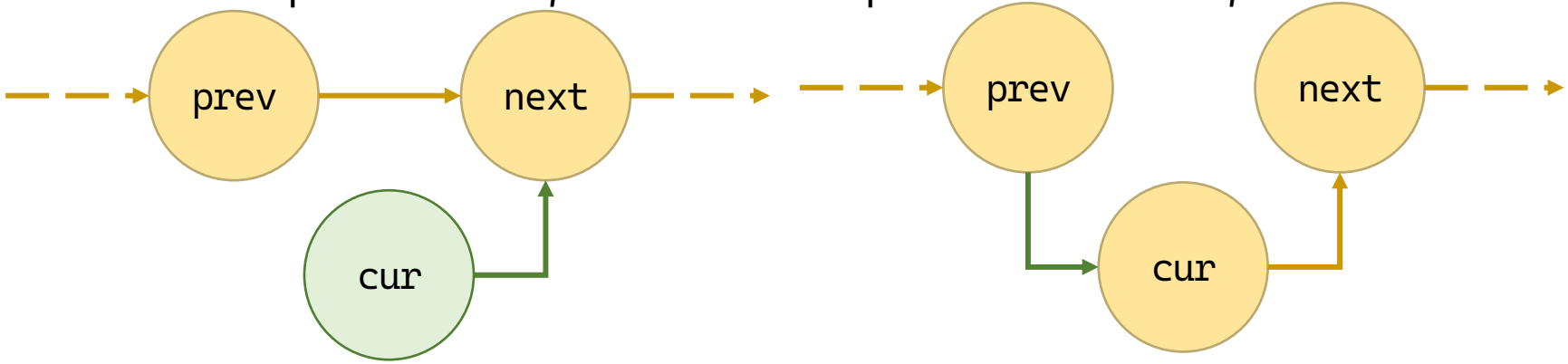
prev=head　　i<offset-1



prev=prev->next

2. cur->next=prev->next;

3. prev->next=cur;

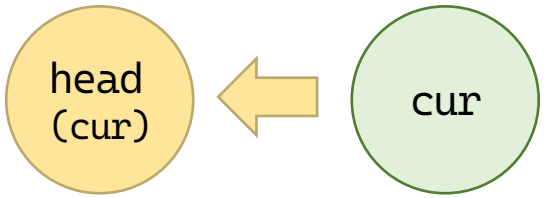


插入元素

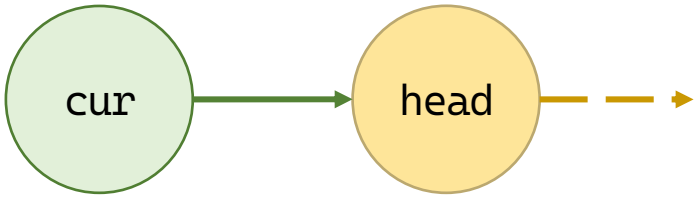
- 在头插入的情况

1. head=NULL;

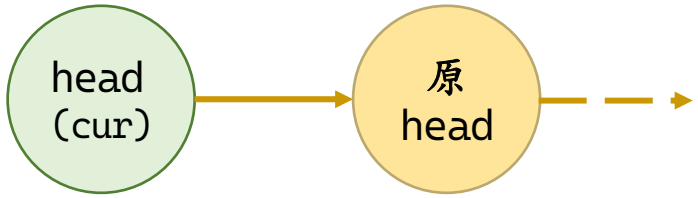
2. head=cur; //当head为NULL



1. cur->next=head;



2. head=cur; //当head不为NULL



删除元素

- 示例代码

```
int remove_item(linklist* list, const size_t offset, int* data) {
    node* previous = *list, * current = NULL;
    size_t i;
    if (*list == NULL) {
        fputs("Empty list.", stderr);
        return ERROR;
    }
    if (offset == 0) {
        *data = previous->data;
        *list = previous->next;
        free(previous);
        return OK;
    }
```

在头删除的情况：
调整结点链接，当前链表头后移；
释放原链表头。

删除元素

- 示例代码

```
    for (i = 0; i < offset - 1 && previous->next; ++i)
        previous = previous->next;
    current = previous->next;
    if (current == NULL) {
        fputs("Failed to find the offset.", stderr);
        return ERROR;
    }
    *data = current->data;
    previous->next = current->next;
    free(current);
    return OK;
}
```

寻找插入位置的前一结点
如果不存在该位置报错

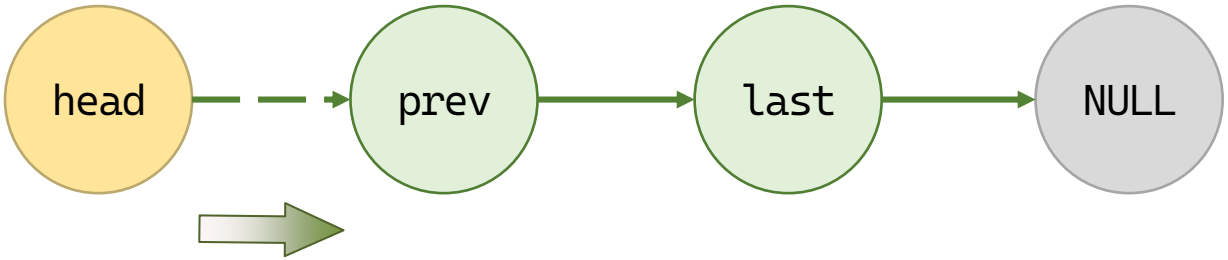
一般删除的情况：
调整结点链接，前一结点跳过待删结点，后续为待删结点的后续；
释放待删结点。

删除元素

- 一般情况

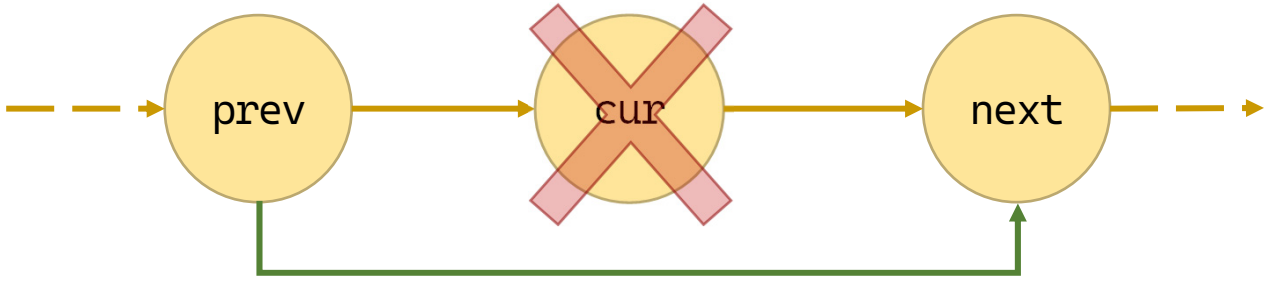
1. 找prev

prev=head　　i<offset-1



prev=prev->next

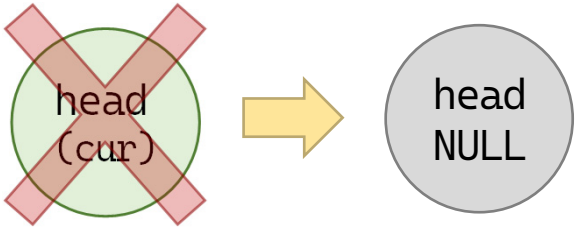
2. prev->next=cur->next; free(cur);



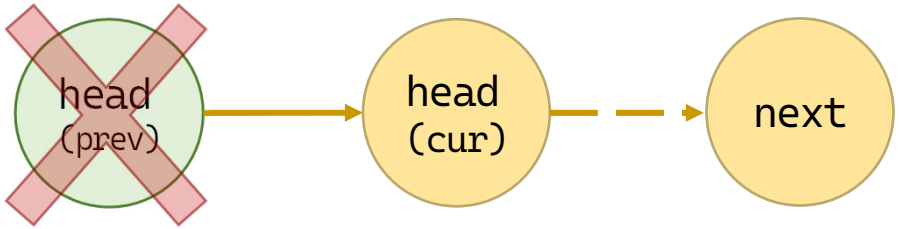
删除元素

- 在头删除的情况

1. `free(head); head=NULL;`



2. `head=prev->next; free(prev);`



链表的销毁

- 示例代码

```
node* destroy(linklist* list) {
    node* current = *list, * next;
    while (current != NULL) {
        next = current->next;
        free(current);
        current = next;
    }
    *list = NULL;
    return NULL;
}
```

```
while (current != NULL) {
    free(current);
    current = current->next;
}
```

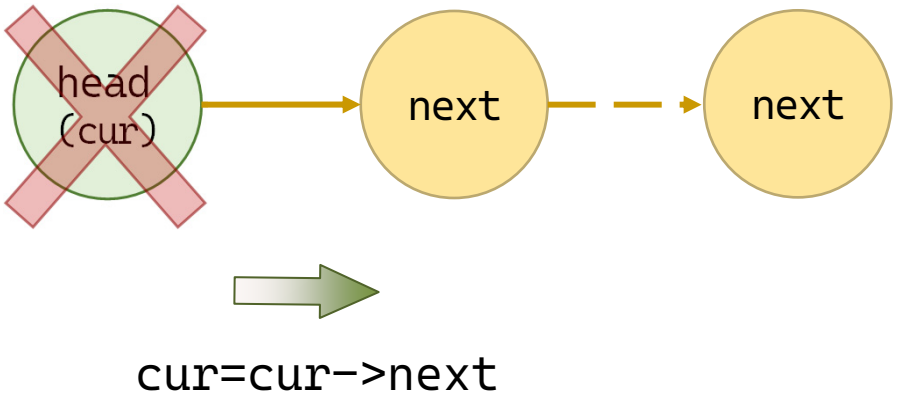
遍历链表

如果先释放cur，则cur->next无效，因此应先暂存该值，再释放

重置链表头为空

链表的销毁

- 由malloc()开辟的空间在程序终止时释放
  - 但程序员不能放任这种情况，应调用free()释放
- 图示



```c
/* films2.c -- using a linked list of structures */
#include <stdio.h>
#include <stdlib.h>      /* has the malloc prototype      */
#include <string.h>      /* has the strcpy prototype      */
#define TSIZE    45      /* size of array to hold title   */
struct film {
    char title[TSIZE];
    int rating;
    struct film* next;  /* points to next struct in list */
};
char* s_gets(char* st, int n);
int main(void) {
    struct film* head = NULL;
    struct film* prev, * current;
    char input[TSIZE];
    /* Gather  and store information          */
    puts("Enter first movie title:");
    while (s_gets(input, TSIZE) != NULL && input[0] != '\0') {
        current = (struct film*)malloc(sizeof(struct film));
        if (head == NULL)       /* first structure       */
            head = current;
```

```
        else                        /* subsequent structures */
            prev->next = current;
        current->next = NULL;
        strcpy(current->title, input);
        puts("Enter your rating <0-10>:");
        scanf("%d", &current->rating);
        while (getchar() != '\n')
            continue;
        puts("Enter next movie title (empty line to stop):");
        prev = current;
    }
    /* Show list of movies                          */
    if (head == NULL)
        printf("No data entered. ");
    else
        printf("Here is the movie list:\n");
    current = head;
    while (current != NULL) {
        printf("Movie: %s  Rating: %d\n",
                current->title, current->rating);
        current = current->next;
    }
```

```
    /* Program done, so free allocated memory */
    current = head;
    while (current != NULL) {
        free(current);
        current = current->next;
    }
    printf("Bye!\n");
    return 0;
}
char* s_gets(char* st, int n) {
    char* ret_val;
    char* find;
    ret_val = fgets(st, n, stdin);
    if (ret_val) {
        find = strchr(st, '\n');  // look for newline
        if (find)                 // if the address is not NULL,
            *find = '\0';         // place a null character there
        else
            while (getchar() != '\n')
                continue;         // dispose of rest of line
    }
    return ret_val;
}
```

思考

扩展内容

- 开辟的内存就一定能成功吗？不成功怎么办？
- 这样的方法可以解决特定问题，但难以添加功能
  - 一个好的程序往往是由小程序不断添加功能长大的
  - 上述程序将“编码细节”与“概念模型”混合在一起

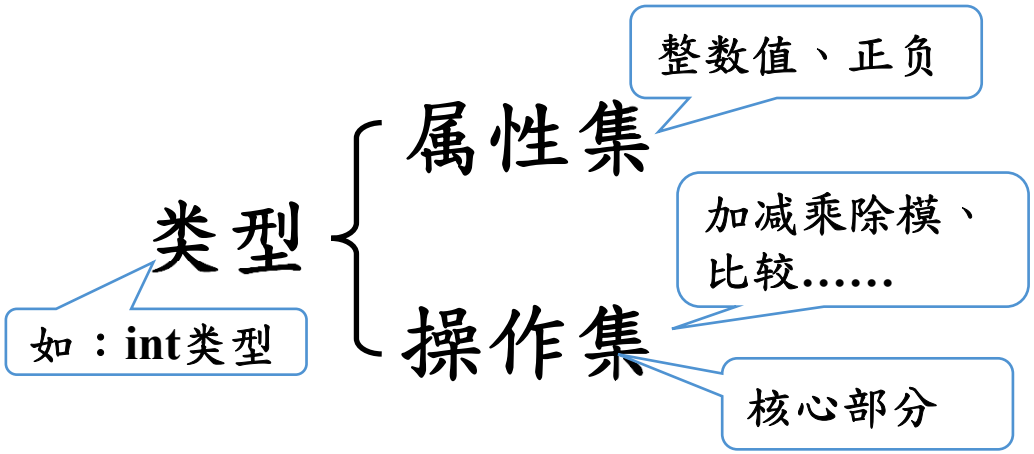
目录

1	高级数据表示
2	链表及其基本操作
3	抽象数据类型

抽象数据类型（ADT）

扩展内容

- 影评系统的具体做法
  - C中没有和合适影评的数据类型，于是我们设计了一个结构体，再变成链表，来表示影评。
- 系统性的做法：定义类型（Type）



抽象数据类型（ADT）

扩展内容

- 类型（type）：由属性集和操作集组成
  - 操作是核心部分，没有操作的数据类型是没有什么用的
    - 设想：一个不能加减乘除的int类型
  - 数学提供了整数的抽象概念，C提供了概念的实现
  - 但是int类型并没有很好地实现整数
    - 长度4B的int型最多为$2^{31}-1$；而整数是无穷的

抽象数据类型（ADT）

扩展内容

- 定义一个新的类型的成功方法
  - 为类型的属性和可对类型执行的操作提供一个抽象的描述
  - 开发一个实现该ADT的编程接口
  - 编写代码来实现这个接口

```c
/* list.h -- header file for a simple list type */
#ifndef LIST_H_
#define LIST_H_
#include <stdbool.h>     /* C99 feature          */

/* program-specific declarations */
#define TSIZE      45    /* size of array to hold title  */
struct film {
    char title[TSIZE];
    int rating;
};

/* general type definitions */
typedef struct film Item;
typedef struct node {
    Item item;
    struct node* next;
} Node;

typedef Node* List;
```

```
/* function prototypes */
/* operation:          initialize a list                          */
/* preconditions:     plist points to a list                     */
/* postconditions:    the list is initialized to empty           */
void InitializeList(List* plist);
/* operation:          determine if list is empty                 */
/*                     plist points to an initialized list        */
/* postconditions:    function returns True if list is empty     */
/*                     and returns False otherwise                */
bool ListIsEmpty(const List* plist);
/* operation:          determine if list is full                  */
/*                     plist points to an initialized list        */
/* postconditions:    function returns True if list is full      */
/*                     and returns False otherwise                */
bool ListIsFull(const List* plist);

/* operation:          determine number of items in list          */
/*                     plist points to an initialized list        */
/* postconditions:    function returns number of items in list */
unsigned int ListItemCount(const List* plist);
```

```
/* operation:         add item to end of list                    */
/* preconditions:     item is an item to be added to list        */
/*                    plist points to an initialized list        */
/* postconditions:    if possible, function adds item to end     */
/*                    of list and returns True; otherwise the    */
/*                    function returns False                     */
bool AddItem(Item item, List* plist);
/* operation:         apply a function to each item in list      */
/*                    plist points to an initialized list        */
/*                    pfun points to a function that takes an    */
/*                    Item argument and has no return value      */
/* postcondition:     the function pointed to by pfun is         */
/*                    executed once for each item in the list    */
void Traverse(const List* plist, void (*pfun)(Item item));
/* operation:         free allocated memory, if any              */
/*                    plist points to an initialized list        */
/* postconditions:    any memory allocated for the list is freed
*/
/*                    and the list is set to empty               */
void EmptyTheList(List* plist);
#endif
```

使用接口

扩展内容

- 先写一些伪代码方案
- 然后不必关心（拘泥于）细节，注重类型和操作即可
- 如何使用接口

```c
/* films3.c -- using an ADT-style linked list */
/* compile with list.c                        */
#include <stdio.h>
#include <stdlib.h>    /* prototype for exit() */
#include "list.h"      /* defines List, Item   */
void showmovies(Item item);
char* s_gets(char* st, int n);
int main(void) {
    List movies;
    Item temp;
    /* initialize       */
    InitializeList(&movies);
    if (ListIsFull(&movies)) {
        fprintf(stderr, "No memory available! Bye!\n");
        exit(1);
    }
    /* gather and store */
    puts("Enter first movie title:");
    while (s_gets(temp.title, TSIZE) != NULL && temp.title[0] != '\0') {
        puts("Enter your rating <0-10>:");
        scanf("%d", &temp.rating);
```

```
        while (getchar() != '\n')
            continue;
        if (AddItem(temp, &movies) == false) {
            fprintf(stderr, "Problem allocating memory\n");
            break;
        }
        if (ListIsFull(&movies)) {
            puts("The list is now full.");
            break;
        }
        puts("Enter next movie title (empty line to stop):");
    }
    /* display           */
    if (ListIsEmpty(&movies))
        printf("No data entered. ");
    else {
        printf("Here is the movie list:\n");
        Traverse(&movies, showmovies);
    }
    printf("You entered %d movies.\n", ListItemCount(&movies));
```

```
    /* clean up           */
    EmptyTheList(&movies);
    printf("Bye!\n");
    return 0;
}
void showmovies(Item item) {
    printf("Movie: %s  Rating: %d\n", item.title, item.rating);
}
char* s_gets(char* st, int n) {
    char* ret_val;
    char* find;
    ret_val = fgets(st, n, stdin);
    if (ret_val) {
        find = strchr(st, '\n'); // look for newline
        if (find)                // if the address is not NULL,
            *find = '\0';        // place a null character there
        else
            while (getchar() != '\n')
                continue;        // dispose of rest of line
    }
    return ret_val;
}
```

实现接口

扩展内容

- 思考你的工作
  - 比较films2.c和list.c，前者暴露了太多的编程细节（高耦合）
  - 如果需要另一个简单的列表，比如电话簿，仍可以通过较少的改动，使用这些文件list.h、list.c
- 这就是面向对象的思想雏形！
  - C语言在实现面向对象时，代码不够简洁
  - 简洁：C++，Java

队列ADT

扩展内容

- 本课程的理论部分到此结束
- 剩下的部分，请自习

```c
/* list.c -- functions supporting list operations */
#include <stdio.h>
#include <stdlib.h>
#include "list.h"
/* local function prototype */
static void CopyToNode(Item item, Node* pnode);
/* interface functions   */
/* set the list to empty */
void InitializeList(List* plist) {
    *plist = NULL;
}
/* returns true if list is empty */
bool ListIsEmpty(const List* plist) {
    if (*plist == NULL)
        return true;
    else
        return false;
}
```

```c
/* returns true if list is full */
bool ListIsFull(const List* plist) {
    Node* pt;
    bool full;
    pt = (Node*)malloc(sizeof(Node));
    if (pt == NULL)
        full = true;
    else
        full = false;
    free(pt);
    return full;
}
/* returns number of nodes */
unsigned int ListItemCount(const List* plist) {
    unsigned int count = 0;
    Node* pnode = *plist;     /* set to start of list */
    while (pnode != NULL) {
        ++count;
        pnode = pnode->next;  /* set to next node     */
    }
    return count;
}
```

```
/* creates node to hold item and adds it to the end of */
/* the list pointed to by plist (slow implementation)  */
bool AddItem(Item item, List* plist) {
    Node* pnew;
    Node* scan = *plist;
    pnew = (Node*)malloc(sizeof(Node));
    if (pnew == NULL)
        return false;     /* quit function on failure  */
    CopyToNode(item, pnew);
    pnew->next = NULL;
    if (scan == NULL)           /* empty list, so place */
        *plist = pnew;          /* pnew at head of list */
    else {
        while (scan->next != NULL)
            scan = scan->next;  /* find end of list     */
        scan->next = pnew;      /* add pnew to end      */
    }
    return true;
}
```

```c
/* visit each node and execute function pointed to by pfun */
void Traverse(const List* plist, void (*pfun)(Item item)) {
    Node* pnode = *plist;    /* set to start of list   */
    while (pnode != NULL) {
        (*pfun)(pnode->item); /* apply function to item */
        pnode = pnode->next;  /* advance to next item   */
    }
}
/* free memory allocated by malloc() */
/* set list pointer to NULL          */
void EmptyTheList(List* plist) {
    Node* psave;
    while (*plist != NULL) {
        psave = (*plist)->next; /* save address of next node */
        free(*plist);           /* free current node         */
        *plist = psave;         /* advance to next node      */
    }
}
/* local function definition  */
/* copies an item into a node */
static void CopyToNode(Item item, Node* pnode) {
    pnode->item = item;  /* structure copy */
}
```

```c
/* queue.h -- interface for a queue */
#ifndef _QUEUE_H_
#define _QUEUE_H_
#include <stdbool.h>
// INSERT ITEM TYPE HERE
// FOR EXAMPLE,
//typedef int Item;  // for use_q.c
// OR typedef struct item {int gumption; int charisma;} Item;
// OR  (for mall.c)
/**/
typedef struct item {
    long arrive;     // the time when a customer joins the queue
    int processtime; // the number of consultation minutes desired
} Item;
/**/
#define MAXQUEUE 10
typedef struct node {
    Item item;
    struct node* next;
} Node;
```

```
typedef struct queue {
    Node* front;  /* pointer to front of queue  */
    Node* rear;   /* pointer to rear of queue*/
    int items;     /* number of items in queue*/
} Queue;
/* operation:        initialize the queue                        */
/* precondition:     pq points to a queue                        */
/* postcondition:    queue is initialized to being empty         */
void InitializeQueue(Queue* pq);
/* operation:        check if queue is full                      */
/* precondition:     pq points to previously initialized queue */
/* postcondition:    returns True if queue is full, else False */
bool QueueIsFull(const Queue* pq);
/* operation:        check if queue is empty                     */
/* precondition:     pq points to previously initialized queue */
/* postcondition:    returns True if queue is empty, else False */
bool QueueIsEmpty(const Queue* pq);
/* operation:        determine number of items in queue          */
/* precondition:     pq points to previously initialized queue */
/* postcondition:    returns number of items in queue            */
int QueueItemCount(const Queue* pq);
```

```
/* operation:          add item to rear of queue                    */
/* precondition:       pq points to previously initialized queue */
/*                     item is to be placed at rear of queue   */
/* postcondition:      if queue is not empty, item is placed at */
/*                     rear of queue and function returns      */
/*                     True; otherwise, queue is unchanged and */
/*                     function returns False                  */
bool EnQueue(Item item, Queue* pq);
/* operation:          remove item from front of queue          */
/* precondition:       pq points to previously initialized queue */
/* postcondition:      if queue is not empty, item at head of  */
/*                     queue is copied to *pitem and deleted from */
/*                     queue, and function returns True; if the */
/*                     operation empties the queue, the queue is */
/*                     reset to empty. If the queue is empty to */
/*                     begin with, queue is unchanged and the  */
/*                     function returns False                  */
bool DeQueue(Item* pitem, Queue* pq);
/* operation:          empty the queue                          */
/* precondition:       pq points to previously initialized queue */
/* postconditions:     the queue is empty                       */
void EmptyTheQueue(Queue* pq);
#endif
```

```c
/* queue.c -- the Queue type implementation*/
#include <stdio.h>
#include <stdlib.h>
#include "queue.h"
/* local functions */
static void CopyToNode(Item item, Node* pn);
static void CopyToItem(Node* pn, Item* pi);
void InitializeQueue(Queue* pq) {
    pq->front = pq->rear = NULL;
    pq->items = 0;
}
bool QueueIsFull(const Queue* pq) {
    return pq->items == MAXQUEUE;
}
bool QueueIsEmpty(const Queue* pq) {
    return pq->items == 0;
}
int QueueItemCount(const Queue* pq) {
    return pq->items;
}
```

```
bool EnQueue(Item item, Queue* pq) {
    Node* pnew;
    if (QueueIsFull(pq))
        return false;
    pnew = (Node*)malloc(sizeof(Node));
    if (pnew == NULL) {
        fprintf(stderr, "Unable to allocate memory!\n");
        exit(1);
    }
    CopyToNode(item, pnew);
    pnew->next = NULL;
    if (QueueIsEmpty(pq))
        pq->front = pnew;           /* item goes to front     */
    else
        pq->rear->next = pnew;      /* link at end of queue   */
    pq->rear = pnew;                /* record location of end */
    pq->items++;                    /* one more item in queue */
    return true;
}
bool DeQueue(Item* pitem, Queue* pq) {
    Node* pt;
    if (QueueIsEmpty(pq))
        return false;
```

```
    CopyToItem(pq->front, pitem);
    pt = pq->front;
    pq->front = pq->front->next;
    free(pt);
    pq->items--;
    if (pq->items == 0)
        pq->rear = NULL;
    return true;
}
/* empty the queue                    */
void EmptyTheQueue(Queue* pq) {
    Item dummy;
    while (!QueueIsEmpty(pq))
        DeQueue(&dummy, pq);
}
/* Local functions                     */
static void CopyToNode(Item item, Node* pn) {
    pn->item = item;
}
static void CopyToItem(Node* pn, Item* pi) {
    *pi = pn->item;
}
```

```c
/* use_q.c -- driver testing the Queue interface */
/* compile with queue.c                          */
#include <stdio.h>
#include "queue.h"  /* defines Queue, Item       */
int main(void) {
    Queue line;
    Item temp;
    char ch;
    InitializeQueue(&line);
    puts("Testing the Queue interface. Type a to add a value,");
    puts("type d to delete a value, and type q to quit.");
    while ((ch = getchar()) != 'q') {
        if (ch != 'a' && ch != 'd')   /* ignore other input */
            continue;
        if (ch == 'a') {
            printf("Integer to add: ");
            scanf("%d", &temp);
            if (!QueueIsFull(&line)) {
                printf("Putting %d into queue\n", temp);
                EnQueue(temp, &line);
            }
```

```
            else
                puts("Queue is full!");
        }
        else {
            if (QueueIsEmpty(&line))
                puts("Nothing to delete!");
            else {
                DeQueue(&temp, &line);
                printf("Removing %d from queue\n", temp);
            }
        }
        printf("%d items in queue\n", QueueItemCount(&line));
        puts("Type a to add, d to delete, q to quit:");
    }
    EmptyTheQueue(&line);
    puts("Bye!");

    return 0;
}
```

```c
// mall.c -- use the Queue interface
// compile with queue.c
#include <stdio.h>
#include <stdlib.h>     // for rand() and srand()
#include <time.h>       // for time()
#include "queue.h"      // change Item typedef
#define MIN_PER_HR 60.0
bool newcustomer(double x);   // is there a new customer?
Item customertime(long when); // set customer parameters
int main(void) {
    Queue line;
    Item temp;                // new customer data
    int hours;                // hours of simulation
    int perhour;              // average # of arrivals per hour
    long cycle, cyclelimit;   // loop counter, limit
    long turnaways = 0;       // turned away by full queue
    long customers = 0;       // joined the queue
    long served = 0;          // served during the simulation
    long sum_line = 0;        // cumulative line length
    int wait_time = 0;        // time until Sigmund is free
    double min_per_cust;      // average time between arrivals
    long line_wait = 0;       // cumulative time in line
```

```
    InitializeQueue(&line);
    srand((unsigned int)time(0)); // random initializing of rand()
    puts("Case Study: Sigmund Lander's Advice Booth");
    puts("Enter the number of simulation hours:");
    scanf("%d", &hours);
    cyclelimit = MIN_PER_HR * hours;
    puts("Enter the average number of customers per hour:");
    scanf("%d", &perhour);
    min_per_cust = MIN_PER_HR / perhour;
    for (cycle = 0; cycle < cyclelimit; cycle++) {
        if (newcustomer(min_per_cust)) {
            if (QueueIsFull(&line))
                turnaways++;
            else {
                customers++;
                temp = customertime(cycle);
                EnQueue(temp, &line);
            }
        }
        if (wait_time <= 0 && !QueueIsEmpty(&line)) {
            DeQueue(&temp, &line);
```

```
            wait_time = temp.processtime;
            line_wait += cycle - temp.arrive;
            served++;
        }
        if (wait_time > 0)
            wait_time--;
        sum_line += QueueItemCount(&line);
    }
    if (customers > 0) {
        printf("customers accepted: %ld\n", customers);
        printf("  customers served: %ld\n", served);
        printf("       turnaways: %ld\n", turnaways);
        printf("average queue size: %.2f\n",
               (double)sum_line / cyclelimit);
        printf(" average wait time: %.2f minutes\n",
               (double)line_wait / served);
    }
    else
        puts("No customers!");
    EmptyTheQueue(&line);
    puts("Bye!");
    return 0;
}
```

```
// x = average time, in minutes, between customers
// return value is true if customer shows up this minute
bool newcustomer(double x) {
    if (rand() * x / RAND_MAX < 1)
        return true;
    else
        return false;
}
// when is the time at which the customer arrives
// function returns an Item structure with the arrival time
// set to when and the processing time set to a random value
// in the range 1 - 3
Item customertime(long when) {
    Item cust;

    cust.processtime = rand() % 3 + 1;
    cust.arrive = when;

    return cust;
}
```

```c
/* tree.h -- binary search tree                              */
/*           no duplicate items are allowed in this tree */
#ifndef _TREE_H_
#define _TREE_H_
#include <stdbool.h>
/* redefine Item as appropriate */
#define SLEN 20
typedef struct item {
    char petname[SLEN];
    char petkind[SLEN];
} Item;
#define MAXITEMS 10
typedef struct trnode {
    Item item;
    struct trnode* left;  /* pointer to right branch  */
    struct trnode* right; /* pointer to left branch   */
} Trnode;
typedef struct tree {
    Trnode* root;          /* pointer to root of tree  */
    int size;               /* number of items in tree  */
} Tree;
```

```
/* function prototypes */
/* operation:      initialize a tree to empty          */
/* preconditions:  ptree points to a tree              */
/* postconditions: the tree is initialized to empty    */
void InitializeTree(Tree* ptree);
/* operation:      determine if tree is empty          */
/* preconditions:  ptree points to a tree              */
/* postconditions: function returns true if tree is    */
/*                 empty and returns false otherwise   */
bool TreeIsEmpty(const Tree* ptree);
/* operation:      determine if tree is full           */
/* preconditions:  ptree points to a tree              */
/* postconditions: function returns true if tree is    */
/*                 full and returns false otherwise    */
bool TreeIsFull(const Tree* ptree);
/* operation:      determine number of items in tree   */
/* preconditions:  ptree points to a tree              */
/* postconditions: function returns number of items in */
/*                 tree                                */
int TreeItemCount(const Tree* ptree);
```

```
/* operation:       add an item to a tree                    */
/* preconditions:   pi is address of item to be added        */
/*                  ptree points to an initialized tree      */
/* postconditions:  if possible, function adds item to       */
/*                  tree and returns true; otherwise,        */
/*                  the function returns false               */
bool AddItem(const Item* pi, Tree* ptree);
/* operation: find an item in a tree                         */
/* preconditions:   pi points to an item                     */
/*                  ptree points to an initialized tree      */
/* postconditions:  function returns true if item is in      */
/*                  tree and returns false otherwise         */
bool InTree(const Item* pi, const Tree* ptree);
/* operation:       delete an item from a tree               */
/* preconditions:   pi is address of item to be deleted      */
/*                  ptree points to an initialized tree      */
/* postconditions:  if possible, function deletes item       */
/*                  from tree and returns true;              */
/*                  otherwise the function returns false*/
bool DeleteItem(const Item* pi, Tree* ptree);
```

```
/* operation:      apply a function to each item in    */
/*                 the tree                            */
/* preconditions:  ptree points to a tree              */
/*                 pfun points to a function that takes*/
/*                 an Item argument and has no return  */
/*                 value                               */
/* postcondition:  the function pointed to by pfun is  */
/*                 executed once for each item in tree */
void Traverse(const Tree* ptree, void (*pfun)(Item item));
/* operation:      delete everything from a tree       */
/* preconditions:  ptree points to an initialized tree */
/* postconditions: tree is empty                       */
void DeleteAll(Tree* ptree);

#endif
```

```c
/* tree.c -- tree support functions */
#include <string.h>
#include <stdio.h>
#include <stdlib.h>
#include "tree.h"
/* local data type */
typedef struct pair {
    Trnode* parent;
    Trnode* child;
} Pair;
/* prototypes for local functions */
static Trnode* MakeNode(const Item* pi);
static bool ToLeft(const Item* i1, const Item* i2);
static bool ToRight(const Item* i1, const Item* i2);
static void AddNode(Trnode* new_node, Trnode* root);
static void InOrder(const Trnode* root, void (*pfun)(Item item));
static Pair SeekItem(const Item* pi, const Tree* ptree);
static void DeleteNode(Trnode** ptr);
static void DeleteAllNodes(Trnode* ptr);
```

```c
/* function definitions */
void InitializeTree(Tree* ptree) {
    ptree->root = NULL;
    ptree->size = 0;
}
bool TreeIsEmpty(const Tree* ptree) {
    if (ptree->root == NULL)
        return true;
    else
        return false;
}
bool TreeIsFull(const Tree* ptree) {
    if (ptree->size == MAXITEMS)
        return true;
    else
        return false;
}
int TreeItemCount(const Tree* ptree) {
    return ptree->size;
}
```

```
bool AddItem(const Item* pi, Tree* ptree) {
    Trnode* new_node;
    if (TreeIsFull(ptree)) {
        fprintf(stderr, "Tree is full\n");
        return false;                  /* early return           */
    }
    if (SeekItem(pi, ptree).child != NULL) {
        fprintf(stderr, "Attempted to add duplicate item\n");
        return false;                  /* early return           */
    }
    new_node = MakeNode(pi);           /* points to new node     */
    if (new_node == NULL) {
        fprintf(stderr, "Couldn't create node\n");
        return false;                  /* early return           */
    }
    /* succeeded in creating a new node */
    ptree->size++;
    if (ptree->root == NULL)           /* case 1: tree is empty  */
        ptree->root = new_node;        /* new node is tree root  */
    else                               /* case 2: not empty      */
        AddNode(new_node, ptree->root); /* add node to tree  */
    return true;                       /* successful return      */
}
```

```
bool InTree(const Item* pi, const Tree* ptree) {
    return (SeekItem(pi, ptree).child == NULL) ? false : true;
}
bool DeleteItem(const Item* pi, Tree* ptree) {
    Pair look;
    look = SeekItem(pi, ptree);
    if (look.child == NULL)
        return false;
    if (look.parent == NULL)      /* delete root item       */
        DeleteNode(&ptree->root);
    else if (look.parent->left == look.child)
        DeleteNode(&look.parent->left);
    else
        DeleteNode(&look.parent->right);
    ptree->size--;
    return true;
}
void Traverse(const Tree* ptree, void (*pfun)(Item item)) {
    if (ptree != NULL)
        InOrder(ptree->root, pfun);
}
```

```
void DeleteAll(Tree* ptree) {
    if (ptree != NULL)
        DeleteAllNodes(ptree->root);
    ptree->root = NULL;
    ptree->size = 0;
}
/* local functions */
static void InOrder(const Trnode* root, void (*pfun)(Item item))
{
    if (root != NULL) {
        InOrder(root->left, pfun);
        (*pfun)(root->item);
        InOrder(root->right, pfun);
    }
}
static void DeleteAllNodes(Trnode* root) {
    Trnode* pright;
    if (root != NULL) {
        pright = root->right;
        DeleteAllNodes(root->left);
        free(root);
```

```
        DeleteAllNodes(pright);
    }
}
static void AddNode(Trnode* new_node, Trnode* root) {
    if (ToLeft(&new_node->item, &root->item)) {
        if (root->left == NULL)       /* empty subtree       */
            root->left = new_node;    /* so add node here    */
        else
            AddNode(new_node, root->left); /* else process subtree */
    }
    else if (ToRight(&new_node->item, &root->item)) {
        if (root->right == NULL)
            root->right = new_node;
        else
            AddNode(new_node, root->right);
    }
    else                              /* should be no duplicates */
    {
        fprintf(stderr, "location error in AddNode()\n");
        exit(1);
    }
}
```

```
static bool ToLeft(const Item* i1, const Item* i2) {
    int comp1;
    if ((comp1 = strcmp(i1->petname, i2->petname)) < 0)
        return true;
    else if (comp1 == 0 &&
             strcmp(i1->petkind, i2->petkind) < 0)
        return true;
    else
        return false;
}
static bool ToRight(const Item* i1, const Item* i2) {
    int comp1;
    if ((comp1 = strcmp(i1->petname, i2->petname)) > 0)
        return true;
    else if (comp1 == 0 &&
             strcmp(i1->petkind, i2->petkind) > 0)
        return true;
    else
        return false;
}
```

```
static Trnode* MakeNode(const Item* pi) {
    Trnode* new_node;
    new_node = (Trnode*)malloc(sizeof(Trnode));
    if (new_node != NULL) {
        new_node->item = *pi;
        new_node->left = NULL;
        new_node->right = NULL;
    }
    return new_node;
}
static Pair SeekItem(const Item* pi, const Tree* ptree) {
    Pair look;
    look.parent = NULL;
    look.child = ptree->root;
    if (look.child == NULL)
        return look;                          /* early return  */
    while (look.child != NULL) {
        if (ToLeft(pi, &(look.child->item))) {
            look.parent = look.child;
            look.child = look.child->left;
        }
```

```
        else if (ToRight(pi, &(look.child->item))) {
            look.parent = look.child;
            look.child = look.child->right;
        }
        else        /* must be same if not to left or right   */
            break; /* look.child is address of node with item */
    }
    return look;                          /* successful return  */
}
static void DeleteNode(Trnode** ptr) {
/* ptr is address of parent member pointing to target node  */
    Trnode* temp;
    if ((*ptr)->left == NULL) {
        temp = *ptr;
        *ptr = (*ptr)->right;
        free(temp);
    }
    else if ((*ptr)->right == NULL) {
        temp = *ptr;
        *ptr = (*ptr)->left;
        free(temp);
    }
```

```
    else    /* deleted node has two children */
    {
        /* find where to reattach right subtree */
        for (temp = (*ptr)->left; temp->right != NULL;
             temp = temp->right)
            continue;
        temp->right = (*ptr)->right;
        temp = *ptr;
        *ptr = (*ptr)->left;
        free(temp);
    }
}
```

```c
/* petclub.c -- use a binary search tree */
#include <stdio.h>
#include <string.h>
#include <ctype.h>
#include "tree.h"

char menu(void);
void addpet(Tree* pt);
void droppet(Tree* pt);
void showpets(const Tree* pt);
void findpet(const Tree* pt);
void printitem(Item item);
void uppercase(char* str);
char* s_gets(char* st, int n);

int main(void) {
    Tree pets;
    char choice;

    InitializeTree(&pets);
```

```
    while ((choice = menu()) != 'q') {
        switch (choice) {
        case 'a':  addpet(&pets);
            break;
        case 'l':  showpets(&pets);
            break;
        case 'f':  findpet(&pets);
            break;
        case 'n':  printf("%d pets in club\n",
                          TreeItemCount(&pets));
            break;
        case 'd':  droppet(&pets);
            break;
        default:  puts("Switching error");
        }
    }
    DeleteAll(&pets);
    puts("Bye.");
    return 0;
}
```

```
char menu(void) {
    int ch;
    puts("Nerfville Pet Club Membership Program");
    puts("Enter the letter corresponding to your choice:");
    puts("a) add a pet          l) show list of pets");
    puts("n) number of pets     f) find pets");
    puts("d) delete a pet       q) quit");
    while ((ch = getchar()) != EOF) {
        while (getchar() != '\n') /* discard rest of line */
            continue;
        ch = tolower(ch);
        if (strchr("alrfndq", ch) == NULL)
            puts("Please enter an a, l, f, n, d, or q:");
        else
            break;
    }
    if (ch == EOF)          /* make EOF cause program to quit */
        ch = 'q';
    return ch;
}
```

```
void addpet(Tree* pt) {
    Item temp;
    if (TreeIsFull(pt))
        puts("No room in the club!");
    else {
        puts("Please enter name of pet:");
        s_gets(temp.petname, SLEN);
        puts("Please enter pet kind:");
        s_gets(temp.petkind, SLEN);
        uppercase(temp.petname);
        uppercase(temp.petkind);
        AddItem(&temp, pt);
    }
}
void showpets(const Tree* pt) {
    if (TreeIsEmpty(pt))
        puts("No entries!");
    else
        Traverse(pt, printitem);
}
```

```
void printitem(Item item) {
    printf("Pet: %-19s  Kind: %-19s\n", item.petname, item.petkind);
}
void findpet(const Tree* pt) {
    Item temp;
    if (TreeIsEmpty(pt)) {
        puts("No entries!");
        return;     /* quit function if tree is empty */
    }
    puts("Please enter name of pet you wish to find:");
    s_gets(temp.petname, SLEN);
    puts("Please enter pet kind:");
    s_gets(temp.petkind, SLEN);
    uppercase(temp.petname);
    uppercase(temp.petkind);
    printf("%s the %s ", temp.petname, temp.petkind);
    if (InTree(&temp, pt))
        printf("is a member.\n");
    else
        printf("is not a member.\n");
}
```

```
void droppet(Tree* pt) {
    Item temp;
    if (TreeIsEmpty(pt)) {
        puts("No entries!");
        return;     /* quit function if tree is empty */
    }
    puts("Please enter name of pet you wish to delete:");
    s_gets(temp.petname, SLEN);
    puts("Please enter pet kind:");
    s_gets(temp.petkind, SLEN);
    uppercase(temp.petname);
    uppercase(temp.petkind);
    printf("%s the %s ", temp.petname, temp.petkind);
    if (DeleteItem(&temp, pt))
        printf("is dropped from the club.\n");
    else
        printf("is not a member.\n");
}
```

```c
void uppercase(char* str) {
    while (*str) {
        *str = toupper(*str);
        str++;
    }
}
char* s_gets(char* st, int n) {
    char* ret_val;
    char* find;
    ret_val = fgets(st, n, stdin);
    if (ret_val) {
        find = strchr(st, '\n');   // look for newline
        if (find)                  // if the address is not NULL,
            *find = '\0';          // place a null character there
        else
            while (getchar() != '\n')
                continue;          // dispose of rest of line
    }
    return ret_val;
}
```

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感谢为本课建设付出的学长和同学们

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17

谢谢观看

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