Linked Lists

Data and File Structures Laboratory

http://www.isical.ac.in/~dfslab/2018/index.html

Traditional implementation


```
typedef struct {
    ...
} DATA;

typedef struct node {
    DATA data;
    struct node *next;
} NODE;


NODE *create_node(DATA d) {
    NODE *nptr;
    if (NULL == (nptr = Malloc(1, NODE)))  /* see common.h for
     definitions */
        ERR_MESG("out of memory");          /* of macros
       */
    nptr->data = d;
    nptr->next = NULL;
    return nptr;
}
```

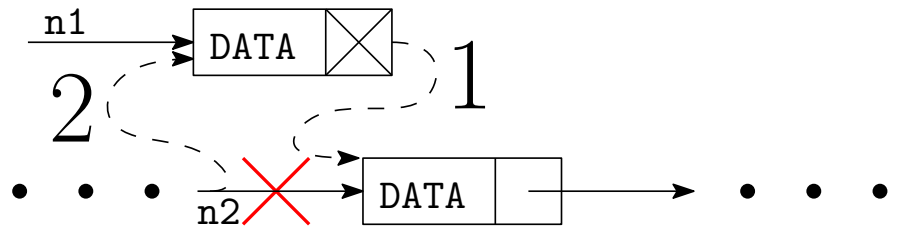
Traditional implementation

Functions:

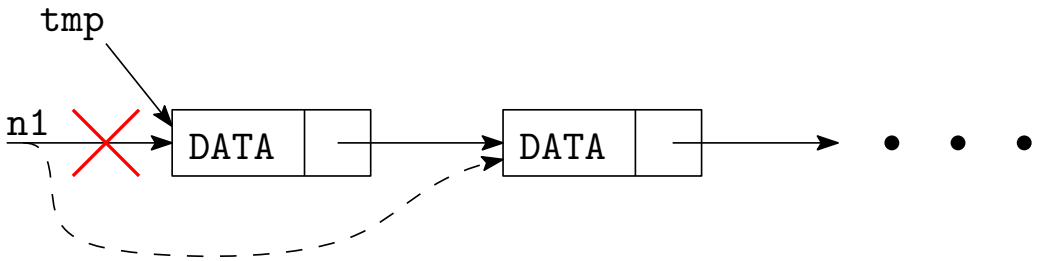
- `create_node()`
- `insert()`
  - insert at beginning / end
  - insert in front of given node ✓
  - insert after given node
- `delete()`
  - delete from beginning / end
  - delete given node ✓

Traditional implementation

```
void insert(NODE *n1, NODE **n2) {
  /* insert n1 in front of n2 */
  if (n1 != NULL) {
     n1->next = *n2;
     *n2 = n1;
  }
}
```




```
void delete(NODE **n1) {
  NODE *tmp;
  if (n1 != NULL && *n1 != NULL) {
     tmp = *n1;
     *n1 = tmp->next;
     free(tmp);
  }
}
```



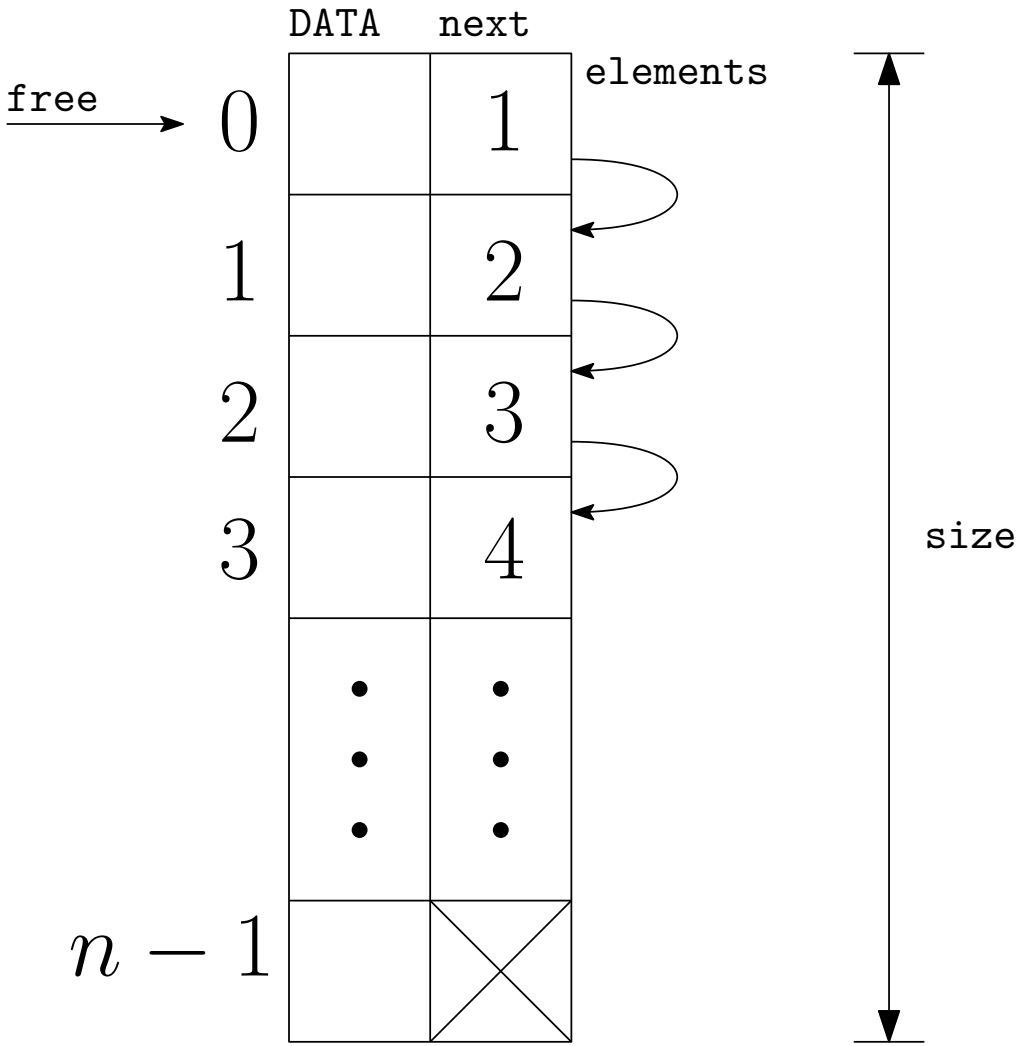
Check if boundary cases are correctly handled!

Alternative implementation

```
typedef struct {
    ...
} DATA;

typedef struct {
    DATA data;
    int next;
} NODE;

typedef struct {
    int head, free;
    int length, size;
    NODE *elements;
} LIST;
```

Alternative implementation

```
typedef struct {
    ...
} DATA;

typedef struct {
    DATA data;
    int next;
} NODE;

typedef struct {
    int head, free;
    int length, size;
    NODE *elements;
} LIST;
```



Alternative implementation

```
LIST create_list(int n) {
    int i;
    LIST l;
    if (NULL ==
        (l.elements = Malloc(n,
     NODE)))
       ERR_MESG("out of memory");
    for (i = 0; i < n-1; i++)
        l.elements[i].next = i+1;
    l.elements[n-1].next = -1;
    l.size = n;
    l.free = 0;
    l.head = -1;
    l.length = 0;
    return l;
}
```

Alternative implementation

```
LIST create_list(int n) {
    int i;
    LIST l;
    if (NULL ==
        (l.elements = Malloc(n,
     NODE)))
       ERR_MESG("out of memory");
    for (i = 0; i < n-1; i++)
        l.elements[i].next = i+1;
    l.elements[n-1].next = -1;
    l.size = n;
    l.free = 0;
    l.head = -1;
    l.length = 0;
    return l;
}
```

```
void insert(LIST *l, DATA *d, int *node)
{ /* insert d in front of node */
  int position = l->free;
  if (-1 == position)
     // no space left; what to do??
  l->free = l->elements[l->free].next;
  l->elements[position].data = *d;
  l->elements[position].next = *node;
  *node = position;
  l->length++;
  }
}
```

Alternative implementation

What to do when no space left

```
if (-1 == position) {
   l->size *= 2;
   if (NULL == Realloc(l->elements, l->size, NODE))
      ERR_MESG("out of memory");
   l->free = l->size/2;
   for (i = l->size/2; i < l->size - 1; i++)
       l->elements[i].next = i+1;
   l->elements[l->size - 1] = -1;
   position = l->free;
}
```

Alternative implementation

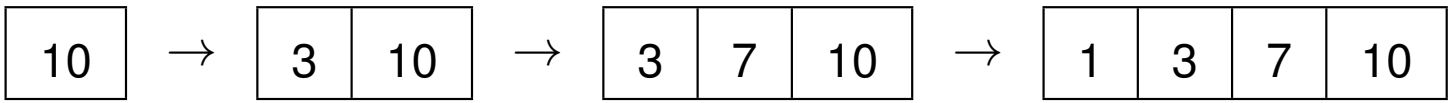
```
void delete(LIST *l, int node;) {
  int tmp;
  if (-1 != node) {
     tmp = l->elements[node].next;
     if (-1 != tmp) {
        l->elements[node].next = l->elements[tmp].next;
        l->elements[tmp].next = l->free;
        l->free = tmp;
        l->length--;
     }
  }
}
```

Problems I

1. Write a program that takes a single positive integer (say N) as a command line argument, generates N random integers between 0 and $10,000$ one by one, and inserts them (one by one) into an initially empty list in sorted order.

   Example:

   Generated elements: 10, 3, 7, 1, . . .

   List: 

   Use the following in turn to store the list:

   (a) an array;

   (b) a “traditional” linked list;

   (c) an array implementation of a linked list.

Problems II

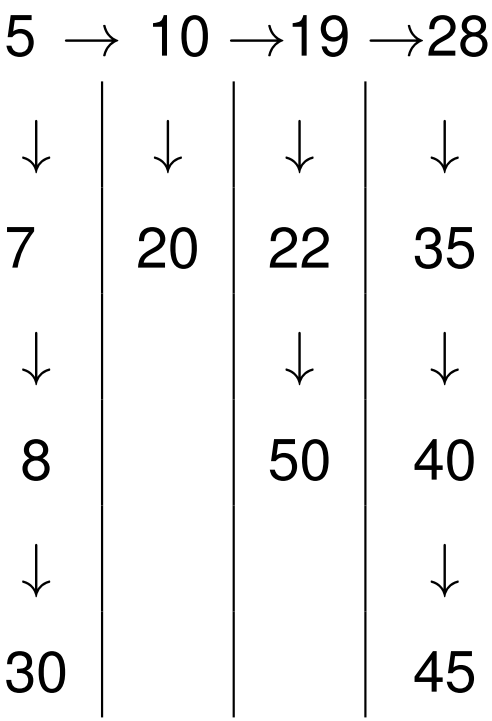
Run your program 5 times each for $N = 100, 500, 1000, 2000, 3000, \ldots, 10000$. Print the sorted list to standard output, and the time taken (followed by a single tab, but no newline) to standard error. Find the average time taken for each value of N and for each implementation method given above. You may use the shell script given below.

2. Modify your program above so that it generates *two* sorted lists instead of one. Write a function to merge these two lists into a single sorted list. For this problem, use traditional linked lists only.

Problems III

3. Write a program that takes a linked list of linked lists, and creates a single flattened linked list, as shown in the example below.

Input



Output

$5 \to 7 \to 8 \to 30 \to 10 \to 20 \to 19 \to 22 \to 50 \to 28 \to 35 \to 40 \to 45$

Input file format:

```
4 # Number of lists
5 7 8 30 # List 1
10 20 # List 2
19 22 50 # List 3
28 35 40 45 # List 4
```

Problems IV

4. Given a list of numbers (provided as command line arguments), write a program to compute the nearest larger value for the number at position i (nearness is measured in terms of the difference in array indices). For example, in the array $[1, 4, 3, 2, 5, 7]$, the nearest larger value for 4 is 5.
   Implement a naive, $O(n^2)$ time algorithm, as well as an $O(n)$ time algorithm for this problem. Compare the run times of your algorithms.

Shell script for Problem 1

```
1  # Assumes that your program prints the time followed by a tab /
       space
2  # e.g. using
3  # printf("%d\t", (int) DURATION(start_time, end_time));
4  cp /dev/null prob1-output.txt
5  for i in 100 500 {1000..10000..1000}; do
6      echo -n "$i "
7      for j in {1..5}; do
8          ./prog1 $i >> prob1-output.txt
9      done
10     echo ""
11 done
```