Doubly linked lists – Special lists

Basics of Programming 1

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4 December, 2024

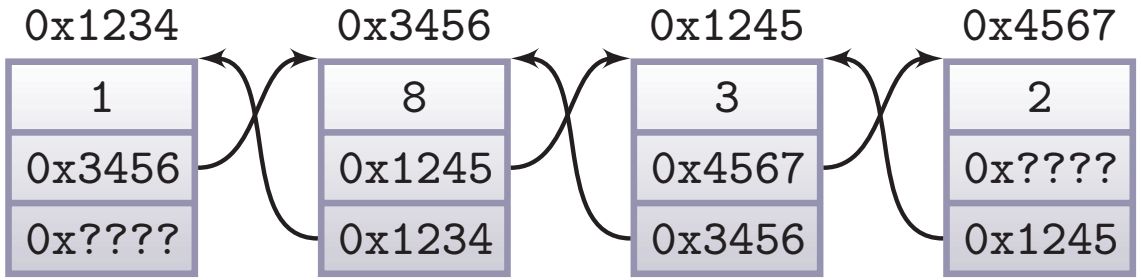
Content

Chapter 1

Doubly linked lists and lists with sentinels

Double linking

- All elements of a doubly linked list contain a pointer to the next and to the previous element too



- Realization in C

```
1  typedef struct listelem {
2    int data;
3    struct listelem *next;
4    struct listelem *prev;
5  } listelem;
```

link

- Doubly linking allows us insertion not only behind but also before an element

Sentinels

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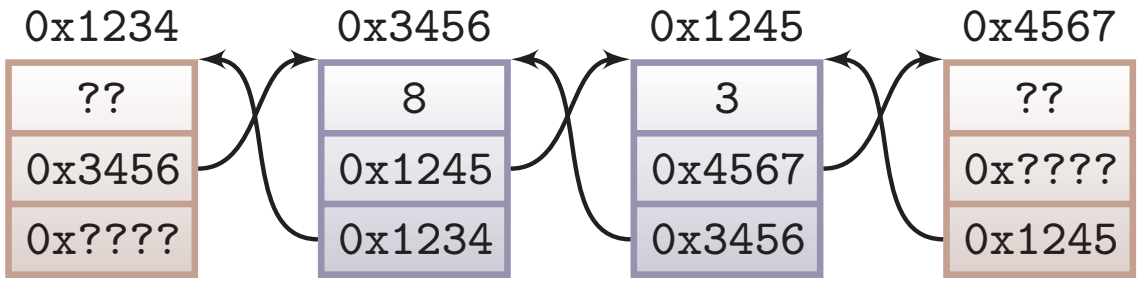
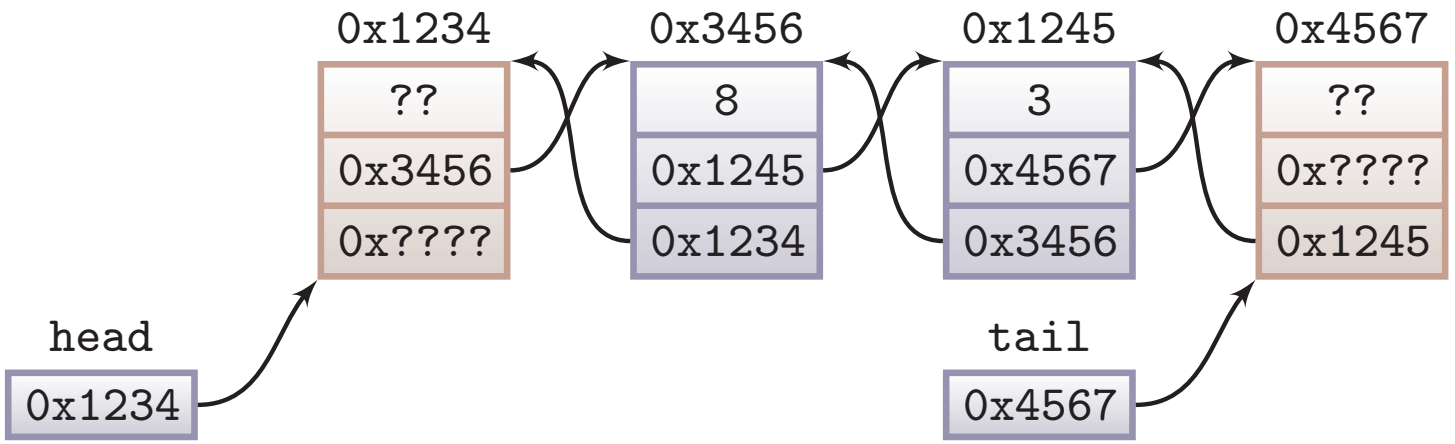
- A list with sentinels means that the list is closed with a non-valid element at one or at both ends, this non-valid element is the sentinel



- The type of the sentinel is the same as the type of the intermediate elements
- The data stored in the sentinel is not part of the list
  - many times its value is not concerned (in an unsorted list)
  - in a sorted list the data contained in the sentinel can be the absolutely largest or absolutely smallest element
- Benefits of the list with two sentinels:
  - insertion – even in case of an empty list – is always done between two elements
  - deletion is always done from between two elements

A doubly linked list with two sentinels

- The sentinels are pointed by the `head` and `tail` pointers



- we enclose these into one entity, this entity will be the list

```
1  typedef struct {
2    listelem *head, *tail;
3  } list;
```

link

- The sentinels are deleted only when clearing up the list, members of `list` are not changed during the usage of the list

Creating an empty list

- The `create_list` function creates an empty list

```
1  list create_list(void)
2  {
3    list l;
4    l.head = (listelem*)malloc(sizeof(listelem));
5    l.tail = (listelem*)malloc(sizeof(listelem));
6    l.head->next = l.tail;
7    l.tail->prev = l.head;
8    return l;
9  }
```

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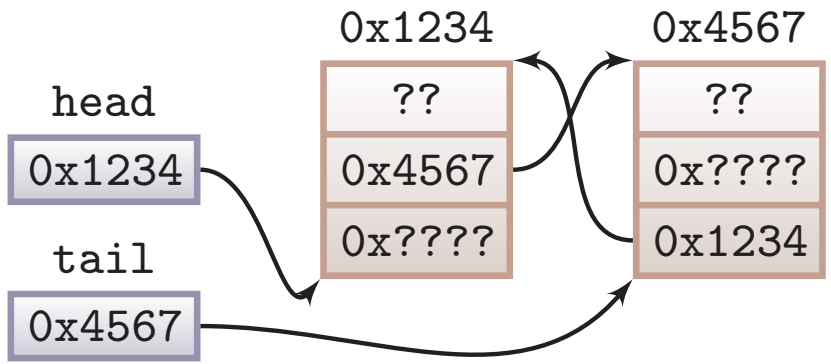

Traversing a list

- The `isempty` function checks whether the list is empty

```
1  int isempty(list l)
2  {
3    return (l.head->next == l.tail);
4  }
```

link

- Traversing a list: with pointer `p` we go from `head->next` to `tail`.

```
1  void print_list(list l)
2  {
3    listelem *p;
4    for (p = l.head->next; p != l.tail; p = p->next)
5      printf("%3d", p->data);
6  }
```

link

Inserting an element between two neighbouring list elements

```
1  void insert_between(listelem *prev, listelem *next,
2    int d)
3  {
4    listelem *p = (listelem*)malloc(sizeof(listelem));
5    p->data = d;
6    p->prev = prev;
7    prev->next = p;
8    p->next = next;
9    next->prev = p;
10 }
```

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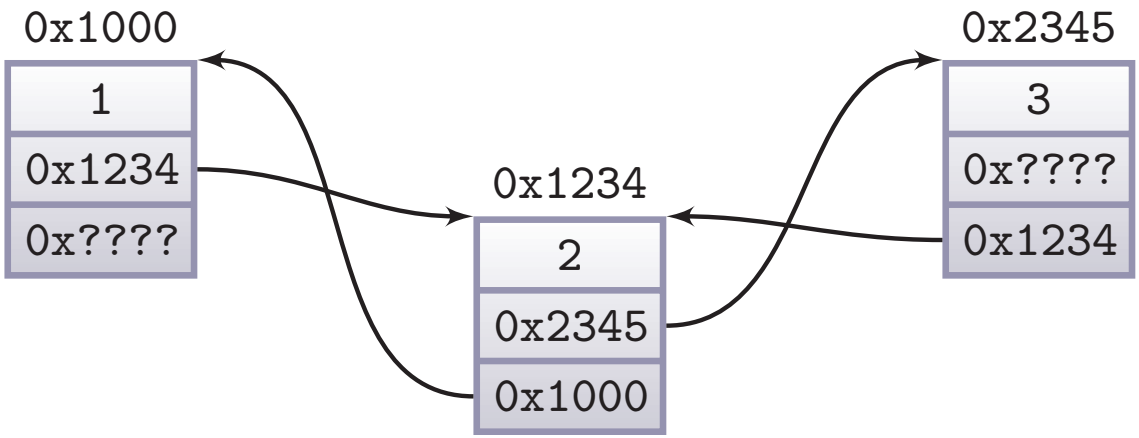

Inserting an element

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- to the front of the list

```
1  void push_front(list l, int d) {
2    insert_between(l.head, l.head->next, d);
3  }
```
link

- to the back of the list (we don't check if it is empty)

```
1  void push_back(list l, int d) {
2    insert_between(l.tail->prev, l.tail, d);
3  }
```
link

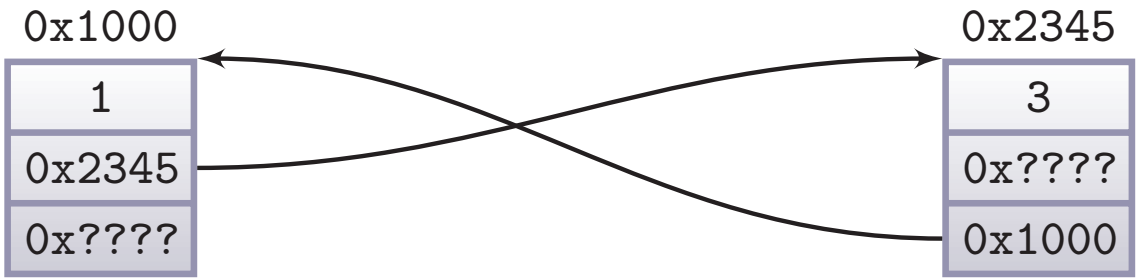
- into a sorted list (we don't need a delayed pointer)

```
1  void insert_sorted(list l, int d) {
2    listelem *p = l.head->next;
3    while (p != l.tail && p->data <= d)
4      p = p->next;
5    insert_between(p->prev, p, d);
6  }
```
link

Deleting an element from a not empty list


```
1  void delete(listelem *p)
2  {
3    p->prev->next = p->next;
4    p->next->prev = p->prev;
5    free(p);
6  }
```

link



Deleting an element from a list

- from the beginning of the list (the deleted data is returned)

```
1  int pop_front(list l)
2  {
3    int d = l.head->next->data;
4    if (!isempty(l))
5      delete(l.head->next);
6    return d; /* if empty, it returns with
7          sentinel garbage */
8  }
```

link

- from the end of the list

```
1  int pop_back(list l)
2  {
3    int d = l.tail->prev->data;
4    if (!isempty(l))
5      delete(l.tail->prev);
6    return d; /* if empty, it returns with
7          sentinel garbage */
8  }
```

link

Deleting an element from a list

- deleting the selected element

```
1  void remove_elem(list l, int d)
2  {
3    listelem *p = l.head->next;
4    while (p != l.tail && p->data != d)
5      p = p->next;
6    if (p != l.tail)
7      delete(p);
8  }
```

link

- deleting the entire list (also the sentinels)

```
1  void dispose_list(list l) {
2    while (!isempty(l))
3      pop_front(l);
4    free(l.head);
5    free(l.tail);
6  }
```

link

Usage

- A simple application

```
1  list l = create_list();
2  push_front(l, -1);
3  push_back(l, 1);
4  insert_sorted(l, -3);
5  insert_sorted(l, 8);
6  remove_elem(l, 1);
7  print_list(l);
8  dispose_list(l);
```

link

- Of course we can store any data in lists, not only `int` values
- It is useful to separate the stored data and the pointers of the list according to the following

```
1  typedef struct {
2    char name[30];
3    int age;
4    ...
5    double height;
6  } data_t;
7
8  typedef struct listelem {
9    data_t data;
10   struct listelem *next, *prev;
11 } listelem;
```

- If the data stored is a single structure type member, then similarly to the case when having only an `int`, we can use it for assignment of value with only one single instruction, it can be a parameter of a function or a return value.

Chapter 2

Special lists

FIFO

FIFO-buffer

FIFO (First In First Out) – we can access the elements in the order of their insertion

- Typical application: queue, where the elements are processed in the order of their arrival
- Realization: eg. with the previous list.
  - for insertion only `push_front`
  - for taking out only `pop_back`

  functions are used.

Stack

Stack (Stack/LIFO-buffer)

LIFO (Last In First Out) – we can access elements in the reversed order of their insertion

- Typical application: storing "undo"-list, storing return addresses of functions
- Realization: eg. with the previous list.
  - for insertion only `push_front`
  - for taking out only `pop_front`

  functions are used.

List sorted in different orders

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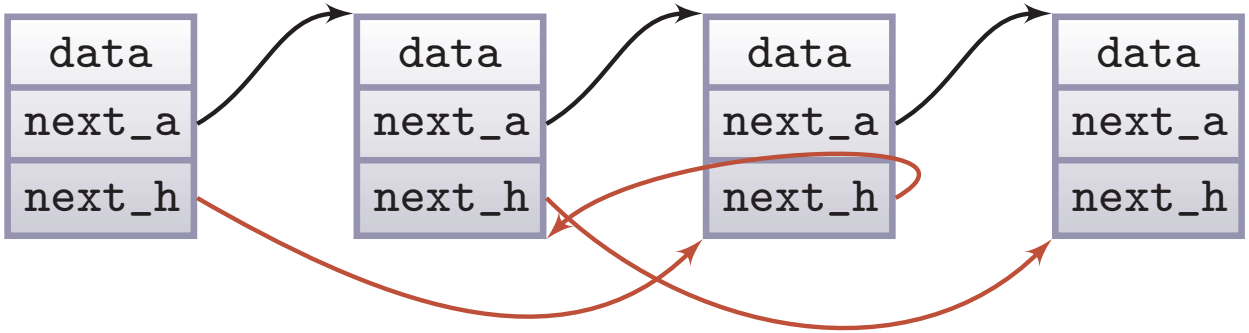
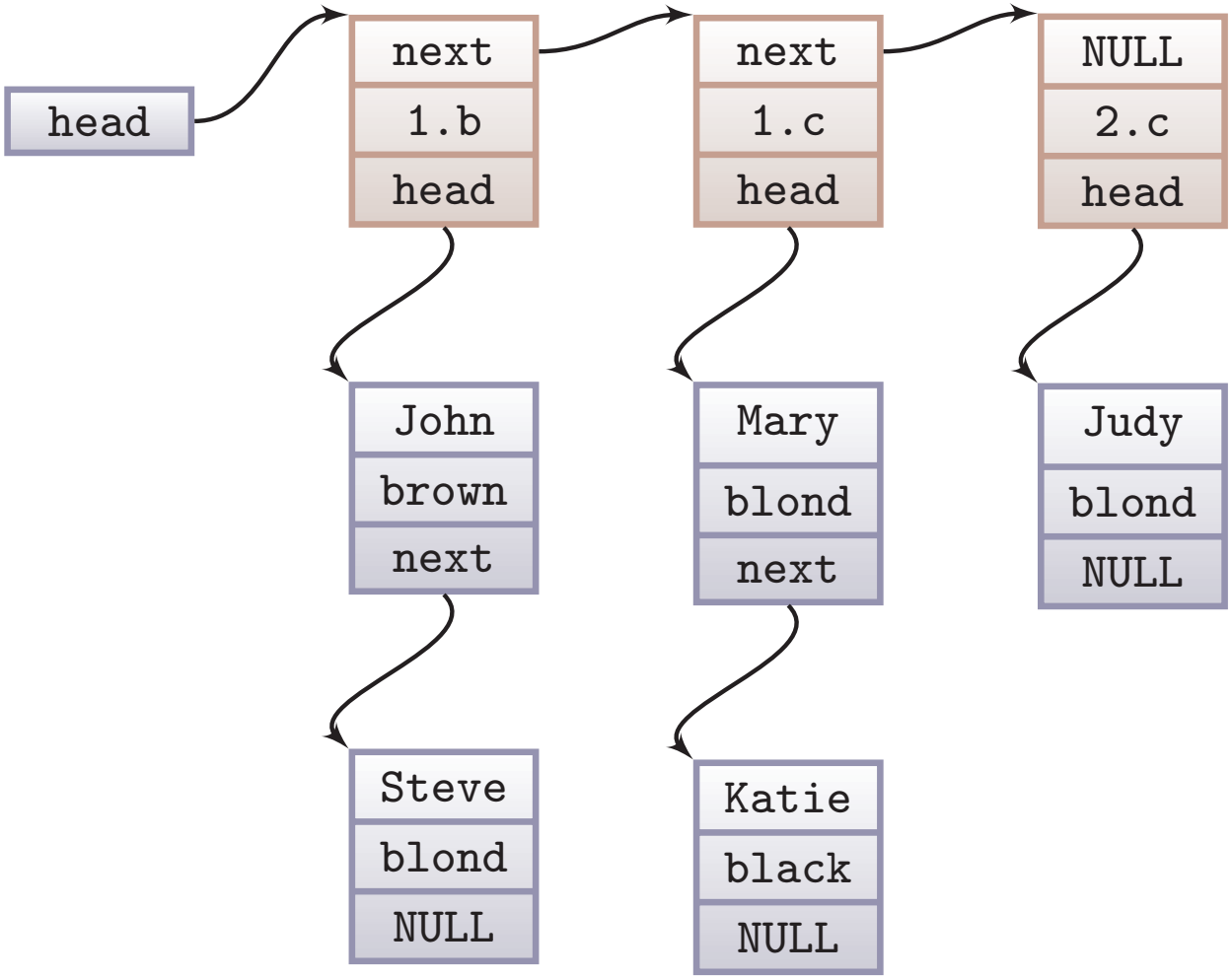
- Type for elements of a list sorted in different orders simultaneously

```
1  typedef struct person {
2    data_t data;                    /* data of person */
3    struct person *next_age;        /* next youngest */
4    struct person *next_height;     /* next smallest */
5  } person;
```



Comb list

- List of classes, where each class contains the list of the students.



Comb list – declarations


```
1  typedef struct student_elem {
2    char name[50];                /* name */
3    colour_t hair_colour;         /* hair colour (typedef) */
4    struct student_elem *next; /* linking */
5  } student_elem;          /* student list element */
6
7  typedef struct class_elem {
8    char name[10];                /* name of class */
9    student_elem *head;           /* list of students */
10   struct class_elem *next;   /* linking */
11 } class_elem;            /* class list element */
```

Comb list – separating data


```
1  typedef struct {
2    char name[50];                 /* name */
3    colour_t hair_colour;          /* hair colour (typedef) */
4  } student_t;                   /* student data */
5
6  typedef struct student_elem {
7    student_t student;             /* the student */
8    struct student_elem *next; /* linking */
9  } student_elem;              /* student list element */
10
11 typedef struct {
12   char name[10];                 /* name of class */
13   student_elem *head;            /* list of student */
14 } class_t;                    /* data for class */
15
16 typedef struct class_elem {
17   class_t class;                 /* the class itself */
18   struct class_elem *next;   /* linking */
19 } class_elem;                /* class list element */
```

Thank you for your attention.