Tutorial 09 - 18.01./21.01.21

Group 02/11 - Moritz Makowski - moritz.makowski@tum.de

Singly-Linked Lists

Today's Agenda

- Singly-Linked Lists in Theory
- Exercise 9.1: Singly-Linked List
- Exercise 9.2: Practice Project - Implementing a Singly-Linked List

List

A list is a **data structure** to **sequentially** store elements in a **specific order**. The order of appearance matters and therefore also the **multiplicity** (how often a certain value exists).

How you implement a list in code is up to you.

Lists as Arrays

Benefits

- **Trivial** implementation
- Very **memory efficient**: Only the lists's length and the list itself needs to be stored.
- Very **efficient indexing**: Accessing (reading/writing) an element at a specific index

Lists as Arrays

Disadvatages

- **Specific length**: Every time the list-memory-space has to increase in size, a new block of memory has to be dynamically allocated with `malloc` / `calloc` .
- **Adding/Removing lists inside the list** requires (depending on the specification) reorganizing the whole remaining list (after that index)
- The **memory has to be "in one peace"** - one long block. Even though there might be enough memory left the whole block may not fit in the free slots in total but only in distributed chunks

Goals of a Solution?

- Flexible length
- flexible refactoring (adding/removing of elements inbetween)
- flexible memory usage (does not require one large block of memory)

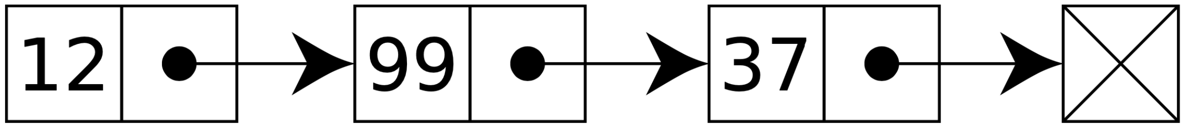
A **singly-linked list** solves all these issues.

Singly-Linked Lists - #1

Each list element - also called **node** - contains its value - and a pointer to the next list element.

The last element of the list contains a NULL-pointer.

The first element is also called **head** and the last element **tail**.



If a pointer stores the value `0`*, it is also called a NULL-pointer.* `0` *is not a valid address!*

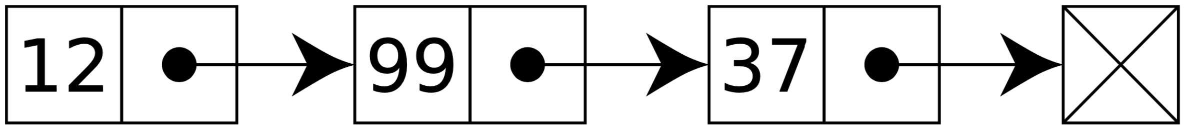
Singly-Linked Lists - #2

In order to store a list like this **we only need to store a pointer to the first list element** or a NULL-pointer in case the list is empty.

We perform most operations by **starting at the head and "traversing through the list"**.

Exercise 9.1: Singly-Linked List

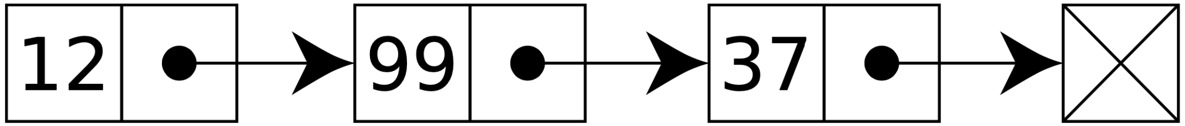
Given the following list, the variable `head_ptr` now contains the pointer to the element with the value 12. What do you have to do (in theory) in order to …



(a) Insert a new node at the front of the list containing the number 144

(b) Delete the node you just inserted from the front of the list

(c) Print every number in the list



(d) Insert a new node containing the number 42 between 12 and 99

(e) Delete the node containing 37 (presume you are not keeping a special tail pointer)

(f) Free the whole list

(g) What would a struct in C look like that represented a **node**?

(h) What would a struct in C look like that represented a **list**?

Exercise 9.2: Practice Project - Singly-Linked List

Now it is you task to actually **implement a singly-linked list in C**.

You can use the following structs as a starting point.

```c
struct Node {
  int value;
  struct Node *next_node;
}

struct List {
  struct Node *head;
}
```

I provided you with a **boilerplate** inside `tutorial-09/examples/list_boilerplate` on GitLab.

Tasks:

- Use **`list.h`** and **`main.c`** as is
- Implement the **list-functionality inside** **`list_boilerplate/list.c`**.
- Implement the functions defined on the following slides.

Compile both boilerplate and solution with:

```
gcc -Wall -Werror -std=c99 list.c main.c -o program.out
```

(a) `init_list` returns the pointer to an initialized struct List (empty). *Hint: Use* *`malloc`* */* *`calloc`* *inside this function.*

```
struct List *init_list();
```

(b) `remove_list` removes a list and `free`s all allocated memory of the struct List and all the struct Node elements inside that list.

```
void remove_list(struct List *list);
```

(c) `append` takes in a value and a list and adds a **new list element** at the **end of the list**

```
void append(struct List *list, int value);
```

(d) `insert` takes in a value, an index and a list and inserts a **new list element** inside the list at the given index. Return 1 if the operation was successful or 0 otherwise (list index out of range).

```
int insert(struct List *list, int value, int index);
```

(e) `remove_by_value` removes all occurances of a given value from the list

```
void remove_by_value(struct List *list, int value);
```

(f) `remove_by_index` removes the list element at a given index and return 1 if the operation was successful or 0 otherwise (list index out of range).

```
int remove_by_index(struct List *list, int index);
```

(g) `get_value_at_index` returns the value of the element at a given index (0 if the element doesn't exist = list index out of range)

```c
int get_value_at_index(struct List *list, int index);
```

(h) `get_index_of_value` returns the index of the first element with the given value (-1 if the value doesn't appear in the list)

```c
int get_index_of_value(struct List *list, int value);
```

In the end your result - when running main - should look like this:

```
[]

Appending 12
[12]

Appending 99
[12, 99]

Appending 12
[12, 99, 12]

Appending 37
[12, 99, 12, 37]

Appending 12
[12, 99, 12, 37, 12]

---------------------


Removing value 12
[99, 37]

Removing value 37
[99]
```

```
Appending 12
Appending 37
Appending 42
[99, 12, 37, 42]

---------------------



Inserting 7 at index 2
[99, 12, 7, 37, 42]

Inserting 4 at index 0
[4, 99, 12, 7, 37, 42]

Inserting 30 at index 6
[4, 99, 12, 7, 37, 42, 30]

Inserting 40 at index 8 (Not possible, list index out of range)
[4, 99, 12, 7, 37, 42, 30]

---------------------



Removing index 2
[4, 99, 7, 37, 42, 30]

Removing index 0
[99, 7, 37, 42, 30]
```

```
[99, 7, 37, 42, 30]
The value at index -1 is 0.
The value at index 0 is 99.
The value at index 1 is 7.
The value at index 2 is 37.
The value at index 3 is 42.
The value at index 4 is 30.
The value at index 5 is 0.

---------------------

[99, 7, 37, 42, 30]
The index of value 99 is 0.
The index of value 7 is 1.
The index of value 37 is 2.
The index of value 42 is 3.
The index of value 30 is 4.
The index of value 5 is -1.
```

Some ideas for more practice ...

```c
// returns the current number of list elements
int length(struct List *list);

// returns the sum of all values stored inside the list
int total(struct List *list);

// returns how many times a given value appears inside the list
int count(struct List *list, int value);

// higher order functions
void map(struct List *list, void (*function)(struct Node *));
void filter(struct List *list, void (*function)(struct Node *));
```

See You Next Week!

All **code examples** and **exercise solutions** on **GitLab** (solutions right after my tutorial):

https://gitlab.lrz.de/dostuffthatmatters/IN8011-WS20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IS TOO DAMN HIGH!
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