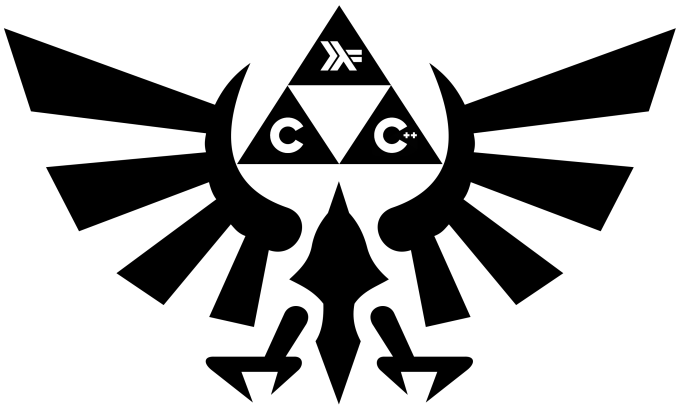
B3 - Paradigms Seminar

B-PDG-300

Rush 2

Standard Kreog Library



2.2

EPITECH.

Rush 2

language: C

- The totality of your source files, except all useless files (binary, temp files, obj files,...), must be included in your delivery.

All your exercises will be compiled with the `-std=gnu17 -Wall -Wextra` **flags**, unless specified otherwise.

All output goes to the standard output.

None of your files must contain a `main` function, unless specified otherwise.
We will use our own `main` functions to compile and test your code.

There are no subdirectories to create for each exercice. Every file must be at the root of the repository.

You will also be evaluated on the quality of your thinking process since the goal of this rush is to get you thinking of several concepts that are new to you , which you'll come to dive into more deeply in the coming weeks.

This rush is inspired by the work of **Axel-Tobias Schreiner**, and more specifically his Objekt-orientierte Programmierung mit ANSI-C.

Obviously, you are more than encouraged to take a look at it.

In the preface of the book, the author talks about his amusement when discovering that the C language can be an **object-oriented language** in its own right.
Of course this made us curious, leading to the dawn of this rush.
Here's hoping you have as much fun as the author!

The rush is split into three main parts:

0. **Reading**

This part introduces some concepts you'll need to master before you go any further.
Do not neglect it!

1. **Design**

This part introduces an "object" design for the C language.
This design does not claim to be perfect, but you will be required to understand and implement it.

2. **Implementation**

Using the object implementation introduced in part 1, you will implement a number of basic types, containers and object-oriented (and generic) algorithms.
All exercises in this part are independent.

Part 0 - Some reading

In this part, we will introduce you to some basic concepts of **Object-Oriented Programming**.

Google and Wikipedia are your friends!

Encapsulation

The problem when creating a type in **C** is that its usage is completely up to the user, they can do anything they want with it.
The only way to protect the user is to give them a set of functions to use the type.
For example, if you define a `player_t` structure, you will have to provide `player_init(player_t *)` and `player_destroy(player_t *)` functions.

This means that for each different type, you'll systematically be coding all the functions which handle the ***objects*** of your program.
For example, for the `player_t` type, you'll prefix all the functions with *"player_"*.
Finding a way to hide the memory representation of a type from the user and group together all the functions that deal with that type is called ***encapsulation***.

This protection guarantees total security to the user, as long as they only use the provided functions to modify the objects.

Types and objects

When declaring a type in C, you must systematically do two things.
The first is to allocate a memory area for the instance and initialize it.
This process is called the ***construction*** of an ***object*** or ***instance***.

The first step, allocating a memory area, is the same for every type, as long as its size is known.
The second step, initialization, differs for each type.
A function, called a ***constructor***, must be called to initialize the object.
The function used to destroy an object is called a ***destructor***.

The set of a type and its member functions (the functions that act on that type) is called a ***class***.
Throughout this rush, we'll explore one of several ways to do **Object-Oriented Programming** in C.

C IMPLEMENTATION

Whatever the author above may think, one has to admit that the C language is not fundamentally object-oriented. How can we deal with that?
In this part, we'll introduce you to the core concepts underlying the design we're suggesting.
Your job is to design all the missing pieces in part 1!

`object.h`

The `object.h` file contains the `Class` type. This is the **type of a type**.
A `Class` object contains the class' name, its size (used when allocating the memory), and function pointers such as the constructor and destructor.

`raise.h`

The `raise.h` file contains the `raise()` macro, which you **MUST** use to handle any error cases (for instance, if `malloc` returns a null pointer). It takes as a single parameter a string indicating the error type.
For instance:

```
if ((ptr = malloc(sizeof(*ptr))) == NULL)
        raise("Out of memory");
```

All it does is print out the message on the error output and exit the program.

`player.h`

The `player.h` file contains the `Player` ***class***.
This description is a bit intriguing, but `player.c` should enlighten you.
The `Player` ***class*** is simply the external declaration of a static variable that describes the class.

You may want to stop reading for a second and read that sentence again while taking a long look at the code.

`Player` is actually a `Class` object, as it describes a type.
This type will be used in order to build and destroy player **instances**.

`player.c`

The `player.c` file contains the **implementation** of the `Player` class. This is where the constructor and destructor will be coded.
You'll also find the `Player` variable we've been talking about so much.
As expected, it contains function pointers for the constructor and destructor which will be used in a transparent manner by `new` and `delete`.

`new.h`

The `new.h` file contains the prototypes for the `new()` and `delete()` functions which let you build and destroy objects.

Part 1 - Simple objects

ex01 - Object construction / destruction

Provided files:

Name	Description
`raise.h`	`raise` macro
`new.h`	`new` and `delete` prototypes
`object.h`	`Class` structure definition
`player.h`	`Player` variable declaration
`player.c`	`Player` class implementation
`ex01.c`	Sample `main` function

Files to turn-in:

Name	Description
`new.c`	`new` and `delete` implementations

The purpose of this exercise is to implement a draft of the `new()` and `delete()` functions.
These will build and destroy `Player` **objects**.
We want to be able to write code such as the following:

```
#include "new.h"
#include "player.h"

int          main(void)
{
    Object  *player = new(Player);

    delete(player);
    return (0);
}
```

This first draft of `new()` simply has to allocate memory according to the class passed as parameter, and then call the class' **constructor if there is one**, ignoring variadic arguments `...`. Similarly, `delete()` must call the **destructor if there is one**, and then free the memory.

malloc(3), memcpy(3)

For the first draft of the new function, forward a NULL va_list pointer to the constructor

EX02 - OBJECT CONSTRUCTION / DESTRUCTION, 2.0

Provided files:

Name	Description
`raise.h`	`raise` macro
`new.h`	`new` and `delete` prototypes
`object.h`	`Class` structure definition
`point.h`	`Point` variable declaration
`point.c`	`Point` class partial implementation
`vertex.h`	`Vertex` variable declaration
`ex02.c`	Sample `main` function

Files to turn-in:

Name	Description
`new.c`	`new` and `delete` implementations
`point.c`	`Point` class implementation
`vertex.c`	`Vertex` class implementation

The previous version of `new()` didn't let us pass parameters to the constructor.
To fix this issue, you must provide a new version of `new()` making use of the C language's support for **variadic arguments**.

stdarg(3)

In addition, to fulfill other needs, you must provide an alternate version of `new()` called `va_new()`.
Here are the prototypes of the functions to turn-in:

```
Object *new(const Class *class, ...);
Object *va_new(const Class *class, va_list *ap);
void delete(Object *ptr);
```

Constructors and destructors will no longer print out messages, be it in this exercise or the next.

It must be possible to use the functions like so:

```
#include "new.h"
#include "point.h"
#include "vertex.h"

int          main(void)
{
     Object  *point = new(Point, 42, -42);
     Object  *vertex = new(Vertex, 0, 1, 2);

     delete(point);
     delete(vertex);

     return (0);
}
```

Create a new `Vertex` class, similar to `Point`.

The `Class` structure now contains a ***member function*** called `__str__`, which returns an allocated string. The `str` macro in `object.h` calls this member function.

snprintf(3)

You must ensure that the following source code:

```
#include "new.h"
#include "point.h"
#include "vertex.h"

int          main(void)
{
     Object  *point = new(Point, 42, -42);
     Object  *vertex = new(Vertex, 0, 1, 2);

     printf("point = %s\n", str(point));
     printf("vertex = %s\n", str(vertex));

     delete(point);
     delete(vertex);

     return (0);
}
```

produces the following output:

```
point = <Point (42, -42)>
vertex = <Vertex (0, 1, 2)>
```

EX03 - OBJECT ADDITION / SUBTRACTION

Provided files:

Name	Description
`raise.h`	`raise` macro
`new.h`	`new` and `delete` prototypes
`object.h`	`Class` structure definition
`point.h`	`Point` variable declaration
`vertex.h`	`Vertex` variable declaration
`ex03.c`	Sample `main` function

Files to turn-in:

Name	Description
`new.c`	`new` and `delete` implementations
`point.c`	`Point` class implementation
`vertex.c`	`Vertex` class implementation

Add two new member functions to the `Class` structure, to let users add and subtract objects.
To comply with these changes, adapt your previous `point.c` and `vertex.c` files to implement the `__add__` and `__sub__` functions.

The following code:

```
#include "new.h"
#include "point.h"
#include "vertex.h"

int          main(void)
{
    Object  *p1 = new(Point, 12, 13);
    Object  *p2 = new(Point, 2, 2);

    printf("%s + %s = %s\n", str(p1), str(p2), str(addition(p1, p2)));
    printf("%s - %s = %s\n", str(p1), str(p2), str(subtraction(p1, p2)));

    Object  *v1 = new(Vertex, 1, 2, 3);
    Object  *v2 = new(Vertex, 4, 5, 6);

    printf("%s + %s = %s\n", str(v1), str(v2), str(addition(v1, v2)));
    printf("%s - %s = %s\n", str(v1), str(v2), str(subtraction(v1, v2)));

    return (0);
}
```

should produce the following output:

```
<Point (12, 13)> + <Point (2, 2)> = <Point (14, 15)>
<Point (12, 13)> - <Point (2, 2)> = <Point (10, 11)>
<Vertex (1, 2, 3)> + <Vertex (4, 5, 6)> = <Vertex (5, 7, 9)>
<Vertex (1, 2, 3)> - <Vertex (4, 5, 6)> = <Vertex (-3, -3, -3)>
```

EX04 - OBJECT ADDITION / SUBTRACTION

Provided files:

Name	Description
`raise.h`	`raise` macro
`new.h`	`new` and `delete` prototypes
`object.h`	`Class` structure definition
`int.h`	`Int` variable declaration
`float.h`	`Float` variable declaration
`char.h`	`Char` variable declaration

Files to turn-in:

Name	Description
`new.c`	`new` and `delete` implementations
`int.c`	`Int` class implementation
`float.c`	`Float` class implementation
`char.c`	`Char` class implementation

This exercise extends, once again, the base class, in addition to re-writing some native C types.
The new types you must implement are `Int`, `Float` and `Char`.
Like in previous exercises, it must be possible to add and subtract objects of the same type, but we also want to be able to multiply, divide and compare them.

Add the following comparison operators to the base class:

- `*` (`__mul__`)
- `/` (`__div__`)
- `==` (`__eq__`)
- `<` (`__lt__`)
- `>` (`__gt__`)

These three classes will be used extensively in the next part.
Operations and comparisons between objects of different types are not required, but could be a bonus :)

The following code must compile and run as expected:

```
void    compareAndDivide(Object *a, Object *b)
{
    if (gt(a, b))
        printf("a > b\n");
    else if (lt(a, b))
        printf("a < b\n");
    else
        printf("a == b\n");

    printf("b / a = %s\n", str(division(b, a)));
}
```

As usual, macros are defined to make calling member functions easier.

PART 2 - GENERIC CONTAINERS

In the previous part, we created simple types.
This section focuses on writing containers.
A container is an object that contains any type of object deriving from the base class.

Let's start by adding an ***intermediate class***, in order to only add member functions to containers.
Adding every member function to every class, like we've been doing so far, would be a lot of work.
An intermediate class is simply a structure containing a `Class` variable, defined like so:s

```
#include "object.h"

typedef struct Container_s
{
        Class base;
        void (*newMethod)(Container *this);
} Container;
```

A `newMethod` function pointer has been added to the `Container` class.

Notice this class *contains* the base class, and must therefore implement all its member functions.

Here's one approach to defining a container in a `.c` file:

```
#include "container.h"

typedef struct MyContainerClass
{
    Container   base;
    int         _val;
}   MyContainerClass;

static const MyContainerClass _descr =
{
    { /* Container struct */
        { /* Class struct */
            .__size__ = sizeof(MyContainerClass)
            .__name__ = "MyContainer",
            /* All Class functions here */
        }
    },
    /* Members of MyContainer */
    ._val = 0
};
```

We have defined a `MyContainer` class *derived* from `Container`, which is itself derived from `Class`.
This is why the `_descr` variable includes the declaration of three nested structures.

The last concept this section introduces is ***iterators***.

An iterator lets you walk through a container, like an index in a table.
To walk through an array in C, you would do something like this:

```
int tab[10];
for (size_t i = 0; i < 10; ++i)
        doStuff();
```

The problem with this approach is that when you decide to change the type of the container, switching to a linked list for instance, you had to change all the code, since iterating through a linked list is done completely differently.

Iterators are a standardized technique for iterating over any type of container. Here is the same sample code, using iterators:

```
Container *tab = new(MyContainer);
for (Iterator *it = begin(tab); lt(it, end(tab)); incr(it))
        doStuff();
```

Notice that the code is very similar, and the meaning behind it stays the same. However, the implementation of the container remains completely hidden.

The `incr` member function is exactly identical to the incrementation of the `i` variable in the previous example: it lets us *move forward* to the next element in the table.
The definition of the `Iterator` class uses the same reasoning as that of `Container`.
It is defined as an intermediate class, used to define other iterators, specific to each container.

EX05 - ARRAY

Provided files:

Name	Description
`raise.h`	`raise` macro
`new.h`	`new` and `delete` prototypes
`object.h`	`Class` structure definition
`container.h`	`Container` structure definition
`iterator.h`	`Iterator` structure definition
`int.h`	`Int` variable declaration
`float.h`	`Float` variable declaration
`char.h`	`Char` variable declaration
`array.h`	`Array` variable declaration
`array.c`	Partial `Array` class implementation
`ex05.c`	Sample `main` function

Files to turn-in:

Name	Description
`new.c`	`new` and `delete` implementations
`int.c`	`Int` class implementation
`float.c`	`Float` class implementation
`char.c`	`Char` class implementation
`array.c`	`Array` class implementation

In this exercise, a partial implementation of the `Array` class is provided, simulating a standard array.
Fill in the functions in the `array.c` file in order to obtain the following behavior:

1. **the constructor** of an `Array` takes as parameters its size (`size_t`), the type contained in the array (`Class *`) and the arguments for the type's constructor.
   For instance, an array of 10 floats, each initialized with `0.0f`:

```
Object *tab = new(Array, 10, Float, 0.0f);
```

2. **the `getitem` member function** takes an index (`size_t`) as parameter and returns the object at that index (`Object *`).

3. **the `setitem` member function** takes an index (`size_t`) as parameter, along with all the arguments to create an new instance of the contained type.
   For instance, a tab with an object at index 3 to replace by a new `Float`, initialized with `42.042f`:

```
setitem(tab, 3, 42.042f);
```

4. **the `setval` member function** of the table iterator works similarly.
   For example:

```
Object *start = begin(tab);
setval(start, 3.14159265f);
```

`va_new()`

EX06 - LIST

Provided files:

Name	Description
`raise.h`	`raise` macro
`new.h`	`new` and `delete` prototypes
`object.h`	`Class` structure definition
`container.h`	`Container` structure definition
`iterator.h`	`Iterator` structure definition
`int.h`	`Int` variable declaration
`float.h`	`Float` variable declaration
`char.h`	`Char` variable declaration

Files to turn-in:

Name	Description
`new.c`	`new` and `delete` implementations
`int.c`	`Int` class implementation
`float.c`	`Float` class implementation
`char.c`	`Char` class implementation
`list.h`	`List` variable declaration
`list.c`	`List` class implementation
`ex06.c`	Sample `main` function

Based on the `Array` class example, create a `List` class that lets users easily manipulate linked lists.
You are free to choose the behaviors you want for the operators (such as `add`), but will have to justify your choices during the defense.

Is it really relevant to multiply lists?

Feel free to add methods if you use a list-specific intermediate class.
It must be possible to use your lists in conjunction with `Array` objects.

A set of tests must be provided in your sample `main` function.

In this part, you are free to modify `container.h`.

Bonus

Impress us!

- Code additional containers (`String` again?)
- Add intermediate classes for `Array` and `List`, defining specific member functions for each of these:
  - `Array.resize`
  - `Array.push_back`
  - `List.push_front`, `List.push_back`
  - `List.pop_front`, `List.pop_back`
  - `List.front`, `List.back`
- Make the previous containers compatible with native C types (`int`, `float`, `char`)
- Make using all these systems safer (no more macros? A magic the number at the beginning of each class? Type verification?)
- Change the design to make it possible to define member functions in an intermediate class
- Make operations between different types possible:
  - `3.0f + 2 = 5.0f`
  - `3 * ['a'] = ['a', 'a', 'a']`
  - `2 * "hello" = "hellohello"`
  - etc...