Intro to C++ Classes
Lecture 23

Today

- Why not `struct`? Why `class`?
- C++ Encapsulation
- C++ Information Hiding
Marrying Data and Functions (Review)

Encapsulation

- bundle related data and operations together

Forge a language construct that joins data and operations together

- use a \textit{struct}! use a \textit{class}! (C++)
- make the functions part of the data type explicitly
  - called \textit{methods}
- similar idea to an \textit{object} in Python

Adds another level of protection against misuse
typedef struct _queue {
    LL_t * intlist;
    void queue_destroy(queue_t * q);
} queue_t;

queue_t * queue_create(void);
void queue_destroy(queue_t * q);
int queue_isEmpty(queue_t * q);
void queue_enqueue(queue_t * q, int data);
int queue_dequeue(queue_t * q);

typedef struct _queue {
    LL_t * intlist;
    void queue_destroy(struct _queue * q);
    int queue_isEmpty(struct _queue * q);
    void queue_enqueue(struct _queue * q, int data);
    int queue_dequeue(struct _queue * q);
} queue_t;

queue_t * queue_create(void);

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    void queue_destroy(queue_t * q);
    int queue_isEmpty(queue_t * q);
    void queue_enqueue(queue_t * q, int data);
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} queue_t;

queue_t * queue_create(void);

typedef struct _queue {
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    void queue_destroy(queue_t * q);
    int queue_isEmpty(queue_t * q);
    void queue_enqueue(queue_t * q, int data);
    int queue_dequeue(queue_t * q);
} queue_t;

queue_t * queue_create(void);

Pointer to a function rather than the function itself

Caller’s notation:
Q->enqueue(Q, x);
which still has a redundant Q.
An Upgrade to C++

Motivated by these interface issues, C++ evolved out of C.

- formulated by Bjarne Stroustrup in 1978

Provides the syntactic sugar for:

- information hiding
- encapsulation of data and methods
- common code re-use situations

Today: Migrate from struct → class
Step 1: The class / public Keywords

Instead of:  
```c
typedef struct _queue {
   LL_t * intlist;
} queue_t;
queue_t * queue_create(void);
void queue_destroy(queue_t * q);
int queue_isEmpty(queue_t * q);
void queue_enqueue(queue_t * q, int data);
int queue_dequeue(queue_t * q);
```

Use:  
```c
class queue {
   public:
   LL_t * intlist;
};
queue * queue_create(void);
void queue_destroy(queue * q);
int queue_isEmpty(queue * q);
void queue_enqueue(queue * q, int data);
int queue_dequeue(queue * q);
```

Adjust types from `queue_t → queue`  

Add the `public:` keyword (just until we get to Step 4)
Step 2: Add The Methods

Migrate the functions into the class definition → methods
- except for _create() and _destroy() which are special cases

Remove the queue_ prefix from method names

Remove parameter queue * q
- every method has direct access to all fields

Methods can use the C++ keyword this if they need such a pointer
Step 3: The class:: Syntax

```cpp
class queue {
    public:
        LL_t * intlist;
        int isEmpty();
        void enqueue(int data);
        int dequeue();
    }

queue * queue_create(void);
void queue_destroy(queue * q);

(int header file queue.h)
```

```cpp
int queue::isEmpty(queue_t * q) {
    return (q->intlist->head == NULL);
}

void queue::enqueue(int data) {
    LLappend(q->intlist, data);
}

int queue::dequeue() {
    return LLremoveHead(q->intlist);
}

(int part of the implementation file queue.cpp)
```

Edit function specifications so they agree with the header

- remove `queue_t * q` for each method
- instead of the prefix `queue_`, use `queue::`

Remove the usage of `q->`

- `intlist` is a member of the class and is treated like a local variable
Some Terminology

A class encapsulates data with its functions

- data members $\rightarrow$ properties
- function members $\rightarrow$ methods

An object is a specific instance of a class

- E.g., The class of all cars have defining properties:
  - colour, make, year, mileage, oil level, etc.

but your car has specific values:

- white, Matrix, 2008, 145 000 km, 52% oil, etc.

Creation of an object is known as instantiation.
Step 4: private Members

To protect class members from external access, use the `private:` keyword

**Rule:** All data members should be kept private.

- Operations on them should be possible only via methods
- This is not merely a matter of style. It’s a matter of:
  - information hiding
  - code independence

```cpp
class queue {
    public:
        LL_t * intlist;
        int isEmpty();
        void enqueue(int data);
        int dequeue();
    }
    private:
        LL_t * intlist;
        public:
            int isEmpty();
            void enqueue(int data);
            int dequeue();
};
```
The Rhythm of _create() Functions

Every _create() function in C so far has followed two steps:

- **allocate** new space on the heap
- **initialize** the data members

In C++, these two steps are separate:

- allocate an object on the heap using the `new` keyword OR . . .
- declare an object locally
- All created objects are initialized by running a special method called a **constructor**

```c
// queue.c
queue * queue_create(void) {
    queue * ret = malloc(sizeof(queue));
    if (ret != NULL) {
        ret->intlist = LLcreate();
    }
    return ret;
}
```

```c
// driver.c
queue * Q = queue_create();
```

```c
// options for driver.cpp
queue * Q = new queue; // heap decl.
queue Q; // local declaration
```
Step 5: Add the Constructor

The constructor method has the same name as the class.
The constructor is always invoked upon instantiation.
- initialize all data members

A constructor can take parameters.
Step 6: Add the Destructor

Destructor is always invoked upon object’s destruction.

- either `delete` operation OR...
- local variable goes out of scope

Clean-up procedure for any resources the object held.

```cpp
class queue {
    private:
        LL_t * intlist;
    public:
        queue();
        int isEmpty();
        void enqueue(int data);
        int dequeue();
    }
}
```

```cpp
queue::~queue() {
    LLdestroy(intlist);
}
```