CS24 Week 2 Lecture 2

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Overview

- Abstract data types
- Introduction to C++
    - Minor C differences
    - Object-oriented programming
    - Objects

Abstract Data Types

High-Level Example

- You have chosen to drive from Santa Barbara to Los Angeles
- You have a driver's license

Questions

- Are these first-priority concerns?
  - The number of cylinders in the vehicle?
  - The gas mileage?
  - Manual or automatic transmission?

Discussion

- Previous questions probably not first concerns
- If it has a steering wheel, brakes, and a gas pedal, it probably is just fine
- The implementation, that is, how the engine works, is **abstract**

Another Example

- We have a program that performs arithmetic on some numbers (+, −, *, /)
- For basic correctness, how important is the mechanism used to represent integers?

Discussion

- Again, representation could vary
  - One's complement
  - Two's complement
  - Binary-coded decimal
  - Inductive definition
- Which representation chosen is not absolutely critical, due to **abstraction**

Abstract Data Types

- A way to abstract over data and the operations on said data
- Intentionally hides detail away

Question

- Why is hiding detail good? (Two big answers)

Answers

- Less information to keep track of
- Implementations can vary independently of how they are used
  - E.g., with a license, you can drive a wide variety of vehicles

Three Levels of ADTs

- There are three levels to an abstract data type:
  - **Application/user level**
  - Logical/abstract level
  - Implementation level

Application/User Level

- Defines the problem domain
- What we need to do with it
  - Examples?

Application/User Level

- Defines the problem domain
- What we need to do with it
- Examples?
  - Where we are driving to
  - The arithmetic we need to perform

Three Levels of ADTs

- There are three levels to an abstract data type:
  - Application/user level
  - **Logical/abstract level**
  - Implementation level

Logical/Abstract Level

- An *abstracted* view of the domain and the operations on the domain
- An interface for using the ADT
- Examples?

Logical/Abstract Level

- An *abstracted* view of the domain and the operations on the domain
- An interface for using the ADT
- Examples?
  - The steering wheel, brake and gas pedals
  - The `+`, `-`, `*`, and `/` operations, along with `int`

Three Levels of ADTs

- There are three levels to an abstract data type:
    - Application/user level
    - Logical/abstract level
    - **Implementation level**

Implementation Level

- How the ADT is implemented "under the hood"
- The code behind the interface
- Examples?

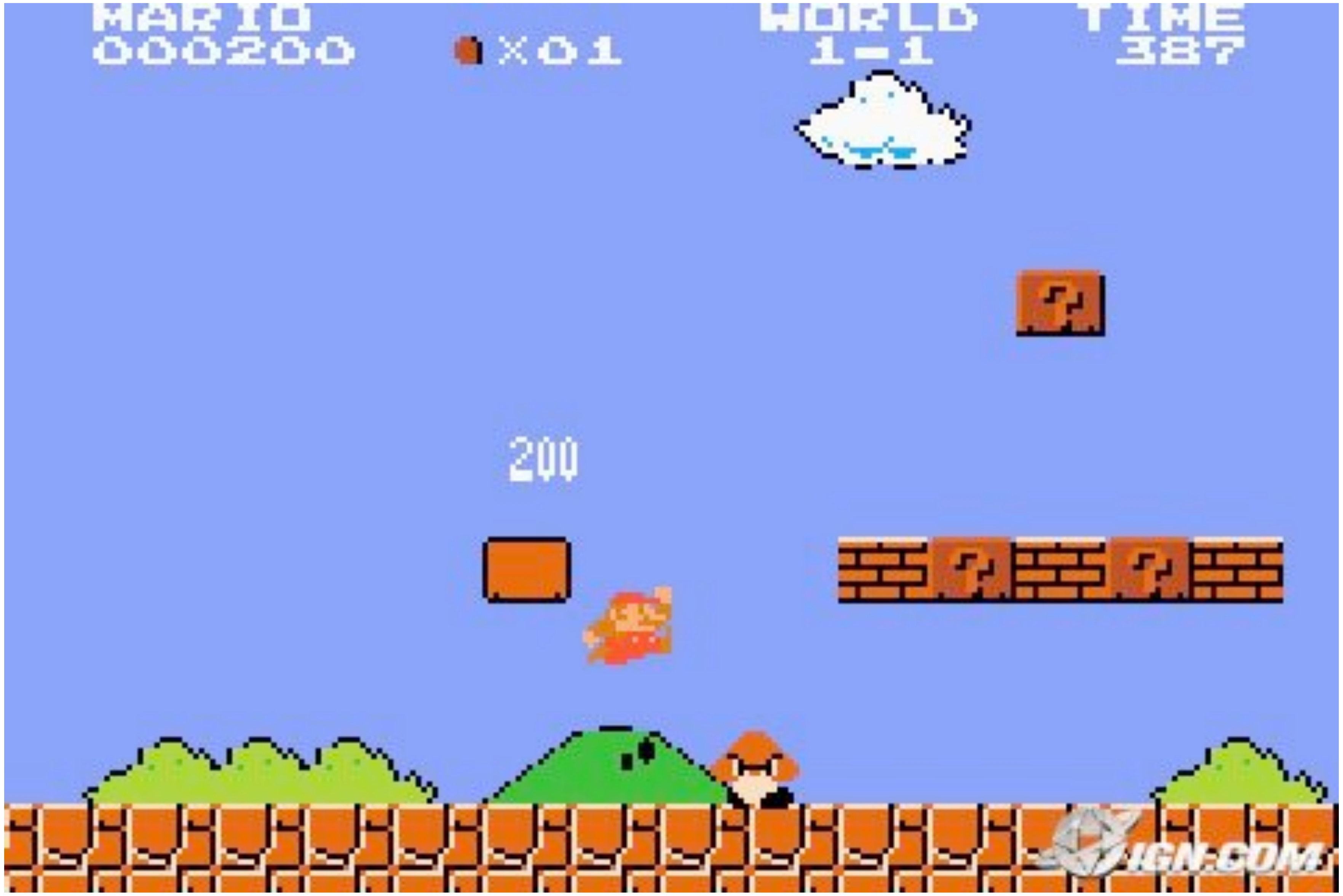
Implementation Level

- How the ADT is implemented “under the hood”
- The code behind the interface
- Examples?
  - The actual engine for the vehicle
  - The integer representation chosen, along with the algorithms for performing the operations

ADT Example in C

Motivation

- A programmer wants to write a 2D platforming game
- The visuals boil down to a grid of rectangles



Important Features

- Players, enemies, platforms, and walls are all rectangles
- In order for the game mechanics to work as expected, we need to be able to
  - Determine and modify the width and height of a rectangle
  - Determine the perimeter of a rectangle
  - Determine the area of a rectangle

Rectangle ADT

- What is the application level?

Rectangle ADT

- What is the application level?
  - The visuals and mechanics of a 2D platforming game

Rectangle ADT

- What about the logical level from a high-level?
  - Recall: width, height, perimeter, area

Rectangle ADT

- What about the logical level as a C interface? (width, height, perimeter, area)
  - Data representation?
  - Representation of operations?
- Try it yourself!

Example in Code

Rectangle ADT

- The implementation level is pretty simple in this case
  - Area = width * height
  - Perimeter = 2 * (width + height)

Problems

- With respect to how we defined ADTs, the C implementation has some issues
- What are these (two major problems)?

Problems

- With respect to how we defined ADTs, the C implementation has some issues
- What are these?
  - A rectangle is a `struct`, and we can always see its internal details
  - The interface is tied to this implementation

Seeing Internal Details

- We often say is this a *leaky* abstraction - it does not abstract over everything it should
- How do we hide function implementation?
- How do we hide `struct` implementation?

Seeing Internal Details

- We often say is this a *leaky* abstraction - it does not abstract over everything it should
- How do we hide function implementation?
  - Header files for interfaces, C files for implementation
- How do we hide `struct` implementation?
  - Just plain **hard** in C; no “accepted” way, and it’s an uphill battle

Interface Tied to Implementation

- The interface-defined `getArea` has only one implementation
- It is not possible to have two functions named `getArea` in C
  - Necessary for a drop-in replacement

Why this Matters - Example

- The game developer notices that the game spends 50% of its time calculating area and perimeter
- The rectangles rarely change their width and height
- How might we make things faster?

Why this Matters - Example

- The game developer notices that the game spends 50% of its time calculating area and perimeter
- The rectangles rarely change their width and height
- How might we make things faster?
  - Precompute area and perimeter, and store them in the rectangle itself

Interface Tied to Implementation

- Precomputing is great for this example
- What if we only need width and height, and we want to minimize the amount of memory used?

Interface Tied to Implementation

- Precomputing is great for this example
- What if we only need width and height, and we want to minimize the amount of memory used?
  - Our original implementation was the best!
  - There is rarely a single perfect implementation

Interface Tied to Implementation

- This can be addressed in C, but it gets very messy
  - Doing it properly requires features we won’t discuss
  - Very error-prone, and leads to bulky code
  - Code basically must determine which implementation is used and respond accordingly

So what if C is bad for this?

- The bulk of this class discusses different kinds of ADTs
- C is really not the language for implementing these properly
- We need a better language for this

C++

Motivation for C++

- C++ has additional features that makes implementing ADTs much cleaner
  - Can hide implementation details much, much better
  - Can vary implementation used relatively easily
  - Can tightly couple data representation with the operations on said data

Design Goals

- Be as close to C as possible
  - Nearly backwards compatible - a superset of C
- Incorporate better support for handling ADTs, and especially *object-oriented programming*

For Now

- Will talk about fundamental differences of C++ next lecture
- For now, I will be covering minor differences
  - You may have to learn these on your own
- Fundamental differences need a whole lecture

Minor C++ Differences

Memory Allocation

`new` instead of `malloc` - non-arrays

```
// in C
int *x1 = malloc(sizeof(int));

// in C++
int *x2 = new int;
```

`new` instead of `malloc` - arrays

```
// in C
int *x1 = malloc(sizeof(int) * 5);

// in C++
int *x2 = new int[5];
```

`delete` instead of `free` - non-arrays

```
// in C
int *x1 = malloc(sizeof(int));
free(x1);

// in C++
int *x2 = new int;
delete x2;
```

`delete[]` instead of `free` - arrays

```
// in C
int *x1 = malloc(sizeof(int) * 5);
free(x1);

// in C++
int *x2 = new int[5];
delete[] x2;
```

`delete` vs. `delete[]`

- Intuitively:
  - `delete` just frees the area
  - `delete[]` frees the area, and calls *object destructors* if it is an array of *objects* (more on those later)
- Undefined what happens if you `delete` (as opposed to `delete[]`) an array

Intermixing Old and New

- Anything allocated with `malloc` should be deallocated with `free`
- Anything allocated with `new` should be deallocated with `delete`
- Intermixing is undefined (`new`/`free` and `malloc`/`delete`)
- Unless you are interoperating with C, use `new` and `delete` exclusively

Overloading

Motivation

- Sometimes, a single operation makes sense in multiple different contexts
  - The `+` operator for `int` and `double`
  - `getArea` for rectangles, squares, and circles
- C limits us here. How?

Motivation

- Sometimes, a single operation makes sense in multiple different contexts
  - The `+` operator for `int` and `double`
  - `getArea` for triangles, rectangles, and circles
- C limits us here. How?
  - `+` is built-in and works this way, but we cannot define anything like this

Solution

- We want to *overload* the definition of getArea
- Overloading based on the *signature* of the function
  - Name of the function
  - Number of arguments
  - Types of arguments
  - **Not** the return type (in C++)

Example

```
double getArea(triangle* t);
double getArea(square* s);
double getArea(circle* c);
```

`const`

Motivation

- A lot of bugs are rooted in unexpected state changes
  - Something unexpectedly changes a variable's value
  - A "read-only" operation wasn't read-only
- We would like a way to guarantee that state cannot change

Example

What is pointed to is constant	The pointer itself is constant

```
void foo(const char* const s) {
  s[0] = 'a'; // disallowed
  s = NULL; // disallowed
}
```

References

Motivation

- Pointers allow us to indirectly refer to data, which is very powerful
- ...but it's also very error-prone
- We want something in between

References

- These "reference" some other data directly
- References are indirect, but they behave as if they were direct
- Unlike pointers, references are not a distinct kind of data that lives in memory (more restricted)
  - Trying to get the address of a reference gets the address of what it references

References Example 1

```
void swapPointers(int* x, int* y) {
  int temp = *x;
  *x = *y;
  *y = temp;
}

void swapRef(int& x, int& y) {
  int temp = x;
  x = y;
  y = temp;
}
```

References Example 2

```
struct point {
  int x;
  int y;
};

void swap(struct point& p) {
  int temp = p.x;
  p.x = p.y;
  p.y = temp;
}

int addedPoint(const struct point& p) {
  return p.x + p.y;
}
```

`#include`

#include

- No longer correct to put `.h` after the filename for **system-provided** files
- Still expected for your own files

```
// provided by system:
#include <iostream>

// provided by you:
#include “myfile.h”
```

Namespaces

Motivation

- Every name (variable, function, `struct`) in C lives in the some distinct *namespace*
- Means we cannot define two variables with the same name at the same scope
  - Global variable pain

Namespaces

- A way for the programmer to define custom namespaces
- In this class, you won't be defining your own, but you will be using existing ones
  - Most notable: `std` for the standard library

Namespaces

- Need to fully specify the name of something
- For example, `endl` is defined in namespace `std`, so to use it we must say:
  - `std::endl`

Namespaces

- Repeatedly typing out the namespace can be annoying, so we can instead say:
  - `using std::endl;`
  - ...and then later simply say `endl` everywhere we would have said `std::endl`

Namespaces

- Sometimes we want everything from a namespace. For that, we can say:
  - `using namespace std;`
  - ...to put everything in the std namespace in scope (no more need to prepend `std::` to everything)

Terminal I/O

Terminal I/O

- Terminal input and output are modeled as *streams* that can be read from and written to
  - `cin`: input stream
  - `cout`: output stream
  - `cerr`: error stream (often synonymous with the output stream)

Reading and Writing

- Can be done using >> and <<, respectively

```
#include <iostream>

using namespace std;

int main() {
  int x;
  cin >> x;
  cout << "Saw: " << x << endl;
  return 0;
}
```