

Ve 280

Programming and Elementary Data Structures

Procedural Abstraction

Learning Objectives:

Understand abstraction, procedural abstraction and their importance

Know how to describe procedural abstraction

Abstraction

- Abstraction
 - Provides only those details that matter.
 - Eliminates unnecessary details and reduces complexity.
- Abstraction is like a black box: we know how to use a black box, but we don't know how it operates
- A person using a black box only needs to know **what** it does, NOT **how** it does it
- Example: Multiplication algorithm
 - Many ways to do: table lookup, summing, etc.
 - Each looks quite different, but they do the **same** thing.
 - In general, a user won't care how it's done, just that it multiplies.

Abstraction

- There are two types of abstraction:
 - Procedural  Focus of this lecture
 - Data

Procedural Abstraction

- **Function** is a way of providing “computational” abstractions.

```
int multi(int a, int b)
{
    // An implementation
    // of multiplication
    ...
}
```



```
int square(int a)
{
    return multi(a, a);
}
```

Using the “multi”
abstraction

Procedural Abstraction

- For any function, there is a person who **implements** the function (**the author**) and a person who **uses** the function (**the client**).
- **The author** needs to think carefully about **what** the function is supposed to do, as well as **how** the function is going to do it.
- In contrast, **the client** only needs to consider the **what**, not the **how**.
- Since **how** is much more complicated, this is a Big Win for **the client**!
- In individual programming, you will often be the author and the client. Sometimes it is to your advantage to “forget the details” and only concentrate on abstraction.

Procedural Abstraction

- Procedural abstractions, done properly, have two important properties:
 - **Local**: the **implementation** of an abstraction does not depend on any other abstraction **implementation**.
 - To realize an implementation, you only need to focus **locally**.
 - **Substitutable**: you can replace one (correct) **implementation** of an abstraction with another (correct) one, and no callers of that abstraction will need to be modified.

Implementation of square() does not depend on **how you implement multi()**

```
int square(int a)
{
    return multi(a,a);
}
```

We can **change** the implementation of multi(). It won't affect square() as long as it does multiplication

Procedural Abstraction

- Locality and substitutability only apply to **implementations** of abstractions, not the **abstractions** themselves.
 - If you change the **abstraction** that is offered, the change is not local.
- It is CRITICALLY IMPORTANT to get the **abstractions** right before you start writing code.

```
int square(int a)
{
    return multi(a,a);
}
```

We cannot change
the abstraction of
“multi” to $2*a*b$.

Procedural Abstraction: Summary

- **Abstraction** and **abstraction implementation** are **different!**
 - Abstraction: tells **what**
 - Implementation: tells **how**
 - **Same** abstraction could have **different** implementations
- If you need to change an **abstraction** itself, it can involve many different changes in the program.
- However, if you only change the **implementation** of an abstraction, then you are guaranteed that no other part of the project needs to change.
 - **This is vital for projects that involve many programmers.**



What are Examples of Using Abstraction?

- A. Using a cell phone
- B. Using a lemma to prove a theorem
- C. Using AND, OR, inverter, etc. to build a digital circuit
- D. Writing an overview paragraph of your paper (i.e., “The rest of the paper is organized as follows: Section II discusses XXX. Section III elaborates YYY. Finally, Section IV concludes the paper.”)



Procedural Abstraction and Function

- **Function** is a way of providing procedure abstractions.
- The **type signature** of a function can be considered as **part of the abstraction**
 - Recall: type signature includes return type, number of arguments and the type of each argument.
 - If you change type signature, callers must also change.
- Besides type signature, we need some way to describe **the abstraction (not implementation)** of the function.
 - We use **specifications** to do this.

Procedural Abstraction

Specifications

- We describe procedural abstraction by specification. It answers three questions:
 - What pre-conditions must hold to use the function?
 - Does the function change any inputs (even implicit ones, e.g., a global variable)? If so, how?
 - What does the procedure actually do?
- We answer each of these three questions in a **specification comment**, and we **always** include one with a **function declaration** (or function definition in case we don't have a declaration)

```
...
```

```
// SPECIFICATION COMMENT
```

```
int add(int a, int b);
```

Procedural Abstraction

Specification Comments

- There are three clauses to the specification:
 - **REQUIRES**: the pre-conditions that must hold, **if any**.
 - **MODIFIES**: how inputs are modified, **if any**.
 - **EFFECTS**: what the procedure computes given legal inputs.
- Note that the first two clauses have an “**if any**”, which means they may be empty, in which case you may omit them.

Procedural Abstraction

Specification Comment Example

```
bool isEven(int n);  
    // EFFECTS: returns true if n is even,  
    // false otherwise
```

- This function returns true if and only if its argument is an even number.
- Since the function isEven is well-defined over all inputs (every possible integer is either even or odd) there needs be no REQUIRES clause.
- Since isEven modifies no (implicit or explicit) arguments, there needs be no MODIFIES clause.

Procedural Abstraction

Specification Comment Example

```
int factorial(int n);  
    // REQUIRES: n >= 0  
    // EFFECTS: returns n!
```

- The mathematical abstraction of factorial is only defined for non-negative integers. So, there is a **REQUIRES** clause.
- The **EFFECTS** clause is only valid for inputs satisfying the **REQUIRES** clause.
- Importantly, this means that the implementation of factorial **DOES NOT HAVE TO CHECK** if $n < 0$! The function specification tells the caller that s/he **must** pass a non-negative integer.

Procedural Abstraction

More Function Details

- Functions without REQUIRES clauses are considered **complete**; they are valid for all input.
- Functions with REQUIRES clauses are considered **partial**
 - Some arguments that are "legal" with respect to the type (e.g., int) are not legal with respect to the function.
- Whenever possible, it is much better to write complete functions than partial ones.
- When we discuss **exceptions**, we will see a way to convert partial functions to complete ones.

Procedural Abstraction

More Function Details

- What about the MODIFIES clause?
- A MODIFIES clause identifies any function argument or global state that **might** change if this function is called.
 - For example, it can happen with pass-by-reference as opposed to pass-by-value inputs.

Procedural Abstraction

Specification Comment Example

```
void swap(int &x, int &y);  
  // MODIFIES: x, y  
  // EFFECTS: exchanges the values of  
  // x and y
```

- NOTE: If the function **could** change a reference argument, the argument must go in the MODIFIES clause. Leave it out only if the function can **never** change it.

Reference

- Procedural Abstraction
 - Problem Solving with C++, 8th Edition, Chapter 4.4 and 5.3