Abstract Data Types (ADTs)

An abstract data type (ADT) is a user-defined type that bundles together:
- the range of values that variables of that type can hold,
- the operations that manipulate variables of that type.

Provides compiler support for your restrictions on values and operations—turns programmer errors into type errors (checked by the compiler).

Can change value range, data representation without changing client source code.

Client Code for Rational ADT

```cpp
#include <iostream>
using namespace std;

int main () {
    Rational r, s;
    cout << "Enter rational number (a/b): ";
    cin >> r;
    cout << "Enter rational number (a/b): ";
    cin >> s;
    Rational t(r+s);
    cout << r << " + " << s << " = " << r+s << endl;
    cout << r << " * " << s << " = " << r*s << endl;
    cout << r << " == " << s << " is " << (r==s) << endl;
    return 0;
}
```

1. Legal Values

A constructor initializes new object to a legal value.

```cpp
class Rational {
public:
    Rational (); // == 0/1
    Rational (int num, int denom) throw (char const*); // == num/1
    explicit Rational (int num); // == num/1
private:
    int numerator_;
    int denominator_;
};
```
### 2. Public Accessors and Mutators

```cpp
class Rational {
public:
    int numerator() const;
    int denominator() const;
    void numeratorIs(const int&);
    void denominatorIs(const int&);
};
```

**Accessors** and **mutators** provide restricted read/update access to data members.
- Want some naming convention.

**Best practice:** Mutators check that client-provided values are within ADT value range.

**Best practice:** Whenever possible,
- pass parameters by `const` reference,
- use `const` member functions.

### 3. Function Overloading

```cpp
class Rational {
public:
    Rational (); // default value == 0/1
    Rational (int num); // value = num/1
    Rational (int num, int denom); // value = num/denom
};
```

**Function overloading** allows you to use the same function name for variants of the same function.
- functions must have different argument signatures
- cannot overload functions that differ only by return type

### 4. Default Arguments

```cpp
class Rational {
public:
    Rational (); // default value == 0/1
    Rational (int num); // value = num/1
    Rational (int num, int denom); // value = num/denom
    Rational (int num = 0, int denom = 1);
};
```

**Use default arguments** to combine variants that vary in user-provided arguments.
- must appear only in the function declaration
- only trailing parameters may have default values
- once one default argument is used in a function call, all subsequent arguments in call must be defaults

### 5. Operator Overloading

```cpp
Rational Rational::operator+ (const Rational &r) const {
    return Rational( numerator() * r.denominator() + denominator() * r.numerator(),
                    denominator() * r.denominator() );
}
```

**Design Decision:** signature of the operator
- argument types, return type, const, pass-by-value/pass-by-reference

**Best Practice:** use operator signatures that the client programmer is used to
(e.g., `operator==` returns a `bool`)
- Cannot create new operations (e.g., `operator*`).
- Cannot change the number of arguments.
6. Non-member Functions

A non-member function is a critical function of the ADT that is declared outside of the class.

- Reduces number of functions with direct access to private data members.
- Some functions have to be non-member functions (e.g., `operator>>`).

Best Practice: Streaming operators should be nonmember functions, so that first operand is reference to stream object.

```cpp
ostream& operator<< (ostream &sout, const Rational &r);
istream& operator>>(istream &sin, Rational &s);
```

Best Practice: Return value is modified stream, so that stream operations can be chained.

```
cout << r << " + " << s << " = " << r+s << endl;
```

7. Type Conversion of ADT objects

```cpp
explicit Rational (int num=0, int denom=1);
```

The compiler uses constructors that have one argument to perform implicit type conversion.

Also true of constructors that have more than one argument, if rest of arguments have default values.

Can prohibit this use of constructors via keyword `explicit`.

8. Private Data Representation

```cpp
class Rational {
public:
    Rational( int num=0, int den=1 );
    int numerator() const;
    int denominator() const;
    void numeratorIs( const int &); // throw (char const*);
    void denominatorIs( const int & ) throw (char const*);
private:
    int numerator_; // throw (char const*);
    int denominator_; // throw (char const*);
};
```

Best Practice: Data members should be private, always.

- ease evolution of the data representation
- client code can access data via public accessors, mutators
- derived classes can manipulate data via public or protected methods
- nonmember functions can manipulate data via public methods or by being a friend
Sometimes we want the default access to be private, but to grant access to select code (e.g., class-related nonmember functions).
- Friends are easier to track than family (when code changes).

```cpp
// Alternate implementation
class Rational {
    friend istream& operator>>(istream&, Rational&);...
};
istream& operator>>(istream &sin, Rational &r) {
    char slash;
    sin >> r.numerator_ >> slash >> r.denominator_;
    return sin;
}
```

**Best Practice:** Hide helper functions as private methods or within a namespace.
- Helper functions modularize code that is common among multiple class-related functions,
- **but** should not pollute the global namespace.

```cpp
class Rational {
    ...
    private:
    void reduce();
    static int gcd(int, int);
};
```

### 10. Override / Final

Applying `override` to a method signifies that the method overrides a virtual function in the base class.

Applying `final` to a virtual function prevents the function from being overridden in derived classes.

`final` may also be applied to a class, in which case the class is prohibited from being used as a base class.

```cpp
class A : B {
    virtual int foo() const final;
    void bar() const override;
};
class Rational final {
    ...
};
```

### Rational

```cpp
class Rational final {
public:
    Rational(int num=0, int den=1);
    int numerator() const;
    int denominator() const;
    void numeratorIs(const int);
    void denominatorIs(const int);
private:
    int numerator_;
    int denominator_;
    void reduce();
    static int gcd(int, int);
};
bool operator==(const Rational&, const Rational&);
bool operator!=(const Rational&, const Rational&);
bool operator<(const Rational&, const Rational&);
bool operator<=(const Rational&, const Rational&);
bool operator>(const Rational&, const Rational&);
bool operator>=(const Rational&, const Rational&);
Rational operator+(const Rational&, const Rational&);
Rational operator-(const Rational&, const Rational&);
Rational operator*(const Rational&, const Rational&);
Rational operator/(const Rational&, const Rational&);
istream& operator>>(istream&, Rational&);
ostream& operator<<(ostream&, Rational&);
```
Summary of Attribute-based ADT Design

Range of legal values
• Default initial value?
• Construct object from client-provided values?
• *explicit* constructors or allow type conversion?
• Throw exception if constructor or mutator is given an illegal value.

Attributes (virtual data members)
• Accessors, mutators; consistent naming scheme

Nonmember functions
• Overloaded functions; default arguments
• Overloaded operators

Final
• Should the client programmer be able to create derived classes?