问题求解与实践
——完成一个计算器

主讲教师： 陈雨亭、沈艳艳

Abstract

- Tokens and token streams
  - Structs and classes
- Cleaning up the code
  - Prompts
  - Program organization
    - constants
  - Recovering from errors
  - Commenting
  - Code review
  - Testing
- A word on complexity and difficulty
  - Variables

Completing the calculator

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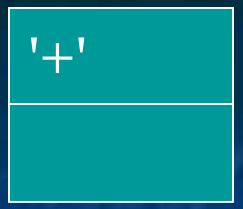
- Now wee need to
  - Complete the implementation
    - Token and Token_stream
  - Get the calculator to work better
  - Add features based on experience
  - Clean up the code
    - After many changes code often become a bit of a mess
    - We want to produce maintainable code



Token

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- We want a type that can hold a "kind" and a value:

```
struct Token {          // define a type called Token
    char kind;          // what kind of token
    double value;       // used for numbers (only): a value
};                      // semicolon is required

Token t;
t.kind = '8';           // . (dot) is used to access members
                        // (use '8' to mean "number")
t.value = 2.3;

Token u = t;            // a Token behaves much like a built-in type, such as int
                        // so u becomes a copy of t
cout << u.value;        // will print 2.3
```

Token

```
struct Token {          // user-defined type called Token
    char kind;          // what kind of token
    double value;       // used for numbers (only): a value
};

Token{'+'};             // make a Token of "kind" '+'
Token{'8',4.5};         // make a Token of "kind" '8' and value 4.5
```

- A **struct** is the simplest form of a class
  - "class" is C++'s term for "user-defined type"
- Defining types is the crucial mechanism for organizing programs in C++
  - as in most other modern languages
- a **class** (including **struct**s) can have
  - data members (to hold information), and
  - function members (providing operations on the data)

Token_stream

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- A **Token_stream** reads characters, producing **Token**s on demand
- We can put a **Token** into a **Token_stream** for later use
- A **Token_stream** uses a "buffer" to hold tokens we put back into it

Token_stream buffer: empty

Input stream: 1+2*3;

For **1+2*3;**, **expression()** calls **term()** which reads **1**, then reads **+,** decides that **+** is a job for **"someone else"** and puts **+** back in the **Token_stream** (where **expression()** will find it)

Token_stream buffer: Token('+')

Input stream: 2*3;

Token_stream

- A **Token_stream** reads characters, producing **Token**s
- **W**e can put back a **Token**

```
class Token_stream {
public:
    // user interface:
    Token get();              // get a Token
    void putback(Token); // put a Token back into the Token_stream
private:
    // representation: not directly accessible to users:
    bool full {false};        // is there a Token in the buffer?
    Token buffer;      // here is where we keep a Token put back using putback()

};

// the Token_stream starts out empty: full==false
```

Token_stream implementation

```
class Token_stream {
public:
    // user interface:
    Token get();                // get a Token
    void putback(Token); // put a Token back into the Token_stream
private:
    // representation: not directly accessible to users:
    bool full {false};          // is there a Token in the buffer?
    Token buffer;       // here is where we keep a Token put back using putback()

};

void Token_stream::putback(Token t)
{
    if (full) error("putback() into a full buffer");
    buffer=t;
    full=true;
}
```

Token_stream implementation

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```
Token Token_stream::get()  // read a Token from the Token_stream
{
    if (full) { full=false; return buffer; }  // check if we already have a Token ready

    char ch;
    cin >> ch;        // note that >> skips whitespace (space, newline, tab, etc.)

    switch (ch) {
    case '(': case ')': case ';': case 'q': case '+': case '-': case '*': case '/':
            return Token{ch};               // let each character represent itself
    case '.':
    case '0': case '1': case '2': case '3': case '4': case '5': case '6': case '7': case '8': case '9':
       {    cin.putback(ch);                // put digit back into the input stream
            double val;
            cin >> val;                     // read a floating-point number
            return Token{'8',val};          // let '8' represent "a number"
       }
    default:
            error("Bad token");
    }
}
```

Streams

- Note that the notion of a stream of data is extremely general and very widely used
  - *Most I/O systems*
    - *E.g.*, C++ standard I/O streams
  - with or without a putback/unget operation
    - We used putback for both **Token_stream** and **cin**

The calculator is primitive

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- We can improve it in stages
  - Style – clarity of code
    - Comments
    - Naming
    - Use of functions
    - …
  - Functionality – what it can do
    - Better prompts
    - Recovery after error
    - Negative numbers
    - % (remainder/modulo)
    - Pre-defined symbolic values
    - Variables
    - …

Prompting

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- Initially we said we wanted

  Expression: 2+3; 5*7; 2+9;
  Result : 5
  Expression: Result: 35
  Expression: Result: 11
  Expression:

- But this is what we implemented

  2+3; 5*7; 2+9;
  5
  35
  11

- What do we really want?

  > 2+3;
  = 5
  > 5*7;
  = 35
  >

Adding prompts and output indicators

```
double val = 0;
cout << "> ";                                  // print prompt
while (cin) {
    Token t = ts.get();
    if (t.kind == 'q') break;                  // check for "quit"
    if (t.kind == ';')
        cout << "= " << val << "\n > ";        // print "= result" and prompt
    else
        ts.putback(t);
    val = expression();                        // read and evaluate expression
}
```

```
> 2+3; 5*7; 2+9;
= 5
> = 35
> = 11
>
```

the program doesn't see input before you hit "enter/return"

"But my window disappeared!"

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- Test case: +1;

```
cout << "> ";                          // prompt
while (cin) {
        Token t = ts.get();
        while (t.kind == ';') t=ts.get();       // eat all semicolons
        if (t.kind == 'q') {
                keep_window_open("~~");
                return 0;
        }
        ts.putback(t);
        cout << "= " << expression() << "\n > ";
}
keep_window_open("~~");
return 0;
```

The code is getting messy

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- Bugs thrive in messy corners
- Time to clean up!
  - Read through all of the code carefully
    - Try to be systematic ("have you looked at all the code?")
  - Improve comments
  - Replace obscure names with better ones
  - Improve use of functions
    - Add functions to simplify messy code
  - Remove "magic constants"
    - E.g. **'8'** (What could that mean? Why **'8'**?)
- Once you have cleaned up, let a friend/colleague review the code ("code review")
  - Typically, do the review together

Remove “magic constants”

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```
// Token “kind” values:
const char number = '8';        // a floating-point number
const char quit = 'q';          // an exit command
const char print = ';';         // a print command

// User interaction strings:
const string prompt = "> ";
const string result = "= ";     // indicate that a result follows
```

Remove "magic constants"

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*// In **Token_stream::get()**:*

```
        case '.':
        case '0': case '1': case '2': case '3': case '4':
        case '5': case '6': case '7': case '8': case '9':
            { cin.putback(ch);                  // put digit back into the input stream
              double val;
              cin >> val;                       // read a floating-point number
              return Token{number,val}; // rather than Token{'8',val}
            }
```

*// In **primary()**:*

```
        case number:            // rather than case '8':
              return t.value;   // return the number's value
```

Remove "magic constants"

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```
// In main():

    while (cin) {
        cout << prompt;                          // rather than "> "
        Token t = ts.get();
        while (t.kind == print) t=ts.get();  // rather than ==';'
        if (t.kind == quit) {                    // rather than =='q'
            keep_window_open();
            return 0;
        }
        ts.putback(t);
        cout << result << expression() << endl;
    }
```

Remove "magic constants"

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- But what's wrong with "magic constants"?
  - Everybody knows **3.14159265358979323846264**, **12**, **-1**, **365**, **24**, **2.7182818284590**, **299792458**, **2.54**, **1.61**, **-273.15**, **6.6260693e-34**, **0.5291772108e-10**, **6.0221415e23** and **42**!
  - No; they don't.
- "Magic" is detrimental to your (mental) health!
  - It causes you to stay up all night searching for bugs
  - It causes space probes to self destruct (well … it can … sometimes …)
- If a "constant" could change (during program maintenance) or if someone might not recognize it, use a symbolic constant.
  - Note that a change in precision is often a significant change; **3.14 !=3.14159265**
  - **0** and **1** are usually fine without explanation, **-1** and **2** sometimes (but rarely) are.
  - **12** can be okay (the number of months in a year rarely changes), but probably is not (see Chapter 10).
- If a constant is used twice, it should probably be symbolic
  - That way, you can change it in one place

So why did we use “magic constants”?

- To make a point
  - Now you see how ugly that first code was
    - just look back to see
- Because we forget (get busy, etc.) and write ugly code
  - “Cleaning up code” is a real and important activity
    - Not just for students
    - Re-test the program whenever you have made a change
  - Every so often, stop adding functionality and “go back” and review code
    - It saves time

Recover from errors

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- Any user error terminates the program
  - That's not ideal
  - Structure of code

```
int main()
try {
    // … do "everything" …
}
catch (exception& e) {        // catch errors we understand something about
    // …
}
catch(…) {                    // catch all other errors
    // …
}
```

Recover from errors

- Move code that actually does something out of main()
  - leave main() for initialization and cleanup only

```
int main()      // step 1
try {
    calculate();
    keep_window_open();          // cope with Windows console mode
    return 0;
}
catch (exception& e) {           // errors we understand something about
    cerr << e.what() << endl;
    keep_window_open("~~");
    return 1;
}
catch (...) {                    // other errors
    cerr << "exception \n";
    keep_window_open("~~");
    return 2;
}
```

Recover from errors

- Separating the read and evaluate loop out into **calculate()** allows us to simplify it
  - no more ugly **keep_window_open()** !

```
void calculate()
{
        while (cin) {
                cout << prompt;
                Token t = ts.get();
                while (t.kind == print) t=ts.get();  // first discard all "prints"
                if (t.kind == quit) return;          // quit
                ts.putback(t);
                cout << result << expression() << endl;
        }
}
```

Recover from errors

- Move code that handles exceptions from which we can recover from **error()** to **calculate()**

```
int main()    // step 2
try {
    calculate();
    keep_window_open();        // cope with Windows console mode
    return 0;
}
catch (...) {                  // other errors (don't try to recover)
    cerr << "exception \n";
    keep_window_open("~~");
    return 2;
}
```

Recover from errors

```
void calculate()
{
    while (cin) try {
        cout << prompt;
        Token t = ts.get();
        while (t.kind == print) t=ts.get();  // first discard all "prints"
        if (t.kind == quit) return;          // quit
        ts.putback(t);
        cout << result << expression() << endl;
    }
    catch (exception& e) {
        cerr << e.what() << endl;            // write error message
        clean_up_mess();                     // <<< The tricky part!
    }
}
```

Recover from errors

- First try

```
void clean_up_mess()
{
    while (true) {              // skip until we find a print
        Token t = ts.get();
        if (t.kind == print) return;
    }
}
```

- Unfortunately, that doesn't work all that well. Why not? Consider the input **1@$z; 1+3;**
  - When you try to **clean_up_mess()** from the bad token **@**, you get a "**Bad token**" error trying to get rid of **$**
  - We always try not to get errors while handling errors

Recover from errors

- Classic problem: the higher levels of a program can't recover well from low-level errors (i.e., errors with bad tokens).
  - Only **Token_stream** knows about characters
- We must drop down to the level of characters
  - The solution must be a modification of **Token_stream**:

```
class Token_stream {public:
    Token get();                // get a Token
    void putback(Token t);      // put back a Token
    void ignore(char c);        // discard tokens up to and including a c
Private:
    bool full {false};          // is there a Token in the buffer?
    Token buffer;  // here is where we keep a Token put back using putback()
};
```

Recover from errors

```
void Token_stream::ignore(char c)
    // skip characters until we find a c; also discard that c
{
    // first look in buffer:
    if (full && c==buffer.kind) {    // && means and
        full = false;
        return;
    }
    full = false;    // discard the contents of buffer
    // now search input:
    char ch = 0;
    while (cin>>ch)
        if (ch==c) return;
}
```

Recover from errors

- clean_up_mess() now is trivial
  - and it works

```
void clean_up_mess()
{
   ts.ignore(print);
}
```

- Note the distinction between what we do and how we do it:
  - **clean_up_mess()** is what users see; it cleans up messes
    - The users are not interested in exactly how it cleans up messes
  - **ts.ignore(print)** is the way we implement **clean_up_mess()**
    - We can change/improve the way we clean up messes without affecting users

Features

- We did not (yet) add
  - Negative numbers
  - % (remainder/modulo)
  - Pre-defined symbolic values
  - Variables
- Read about that in Chapter 7
  - % and variables demonstrate useful techniques
- Major Point
  - Providing "extra features" early causes major problems, delays, bugs, and confusion
  - "Grow" your programs
    - First get a simple working version
    - Then, add features that seem worth the effort

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