ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ
ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ

Εισαγωγή στον Προγραμματισμό
Introduction to Programming

Διάλεξη 6: Ολοκλήρωση προγράμματος

Γ. Παπαγιαννάκης

ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ, ΠΟΛΙΤΙΣΜΟΥ & ΑΘΛΗΤΙΣΜΟΥ
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Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο
ΕΣΠΑ 2007-2013
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

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πρόγραμμα για την ανάπτυξη
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

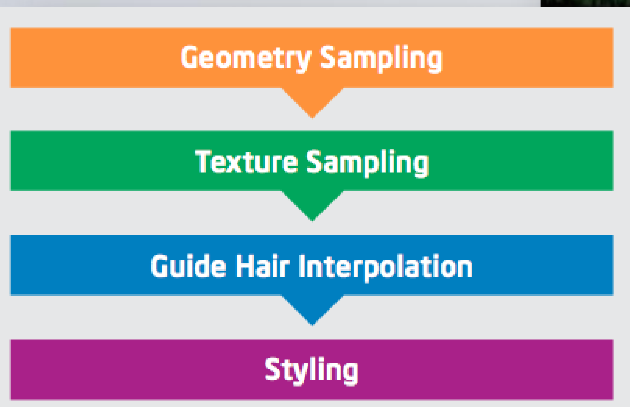
HY-150 Προγραμματισμός
CS-150 Programming

Lecture 6:
Completing a program

G. Papagiannakis

for loops can be critical…

The Parallel Universe, Intel, Issue 9, February 2012




```
void Fur::generateFur()
{
  for(size_t i=0; i<numHairs; i++)
  {
      // compute each hair
  }
}
```

```
void Fur::generateFur()
{
  tbb::parallel_for(
      tbb::blocked_range<size_t>(0,numHairs),
      [=](const tbb::blocked_range<size_t> &r)
      {
          for(size_t i = r.begin() i<r.end(); i++),
          {
              // compute each hair
          }
      } );
}
```

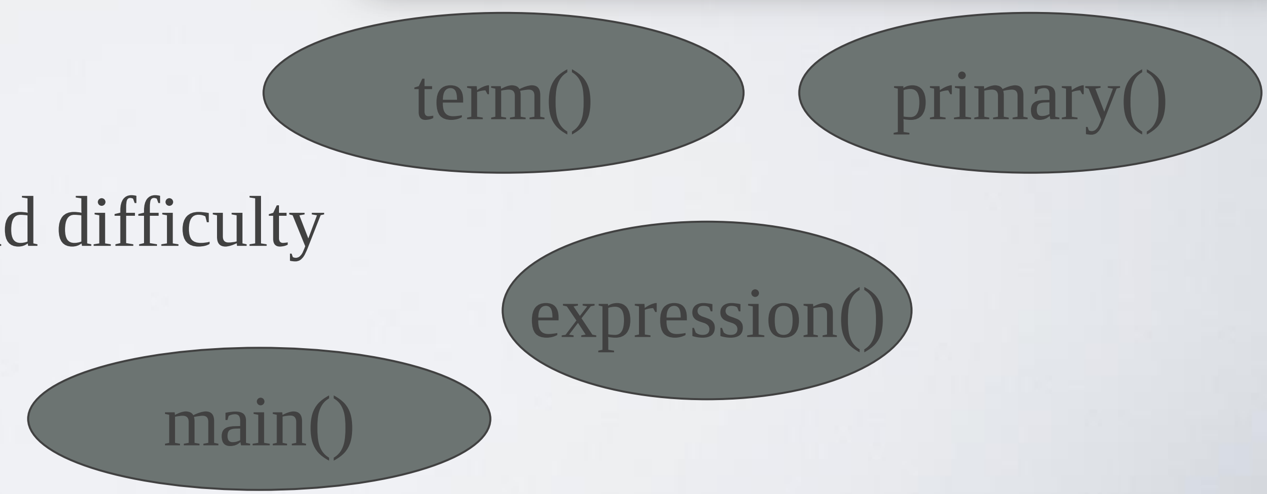
Figure 5: Left-hand side—original fur shader code. Right-hand side—modified code using Intel® TBB `parallel_for` with C++ lambda expression

KungFu Panda 2 HD Trailer (implementation of Fur Shader using parallelized for loops), http://www.youtube.com/watch?v=YdaMGcOyfjM

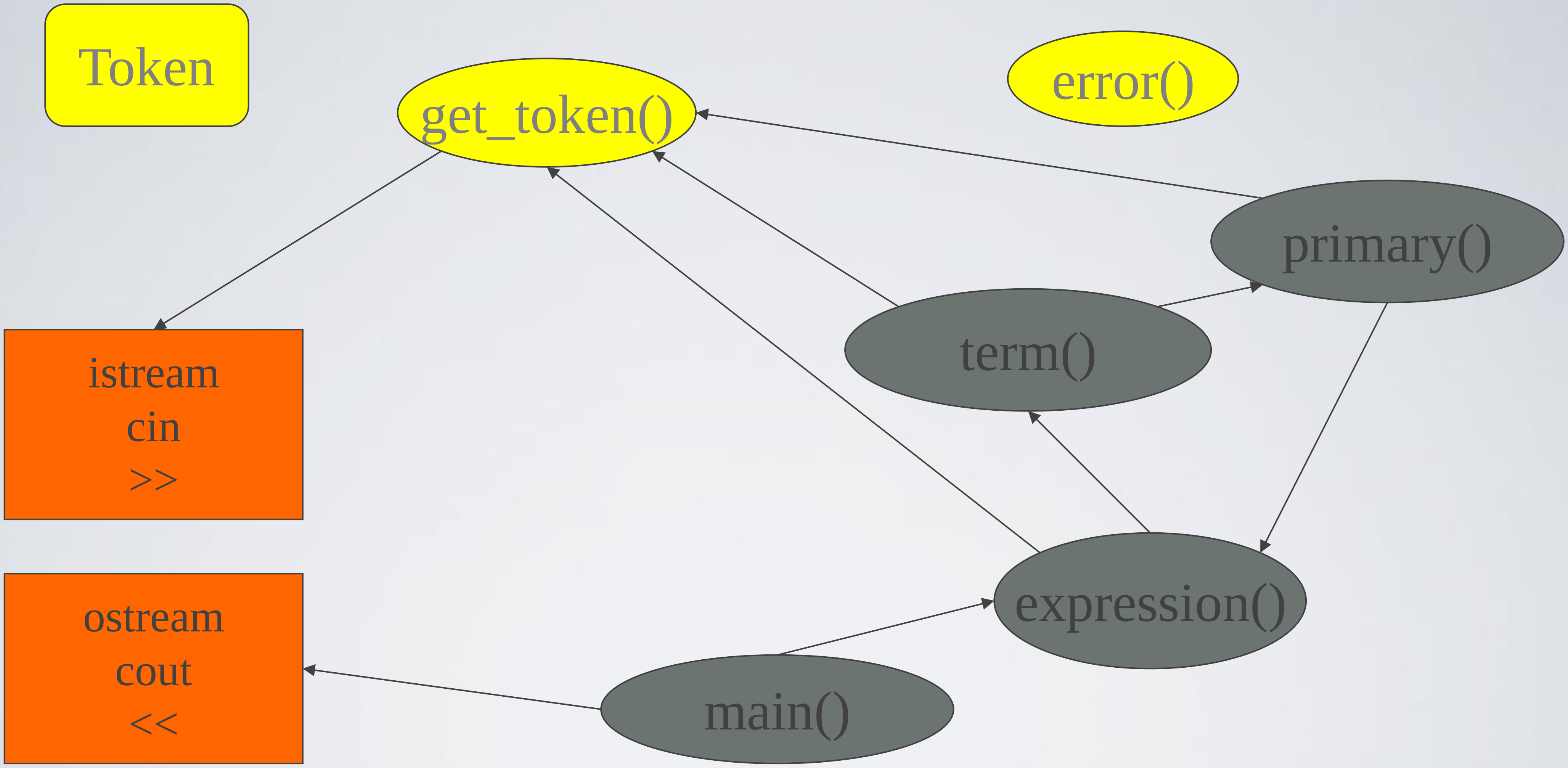
Overview

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

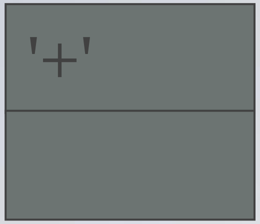
```
Expression:
        Term
        Expression "+" Term        // addition
        Expression "–" Term        // subtraction
Term:
        Primary
        Term "*" Primary           // multiplication
        Term "/" Primary           // division
        Term "%" Primary           // remainder (modulo)
Primary:
        Number
        "(" Expression ")"         // grouping
Number:
        floating-point-literal
```



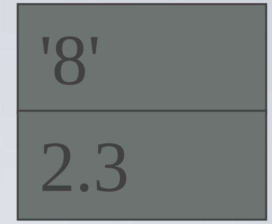
Calculator Program organization



- What we implemented in the last lecture



Token



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

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

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

```
class Token {         // user-defined type called Token
    // data members
    // function members
};
```

- 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

```
class Token {
  char kind;                 // what kind of token
  double value;              // for numbers: a value

  Token(char ch) : kind(ch), value(0) { }                      // constructor
  Token(char ch, double val) : kind(ch), value(val) { }        // constructor
};
```

- A constructor has the same name as its class
- A constructor defines how an object of a class is initialized
  - Here **kind** is initialized with **ch,** and
  - **value** is initialized with **val** or **0**
  - Token('+'); // make a **Token** of “kind” **‘+’**
  - Token('8',4.5); // make a **Token** of “kind” **‘8’** and value **4.5**

Token get_token()

```
Token get_token()    // read a token from cin
{
    char ch;
    cin >> ch;                  // note that >> skips whitespace (space, newline, tab, etc.)

switch (ch) {
    case '(': case ')': 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");
    }
}
```

Token_stream

```
Expression:
    Term
    Expression "+" Term      // addition
    Expression "–" Term      // subtraction
Term:
    Primary
    Term "*" Primary         // multiplication
    Term "/" Primary         // division
    Term "%" Primary         // remainder (modulo)
Primary:
    Number
    "(" Expression ")"       // grouping
Number:
    floating-point-literal
```

- 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
- We can put back a **Token**

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

- A constructor
  - defines how an object of a class is initialized
  - has the same name as its class, and no return type

Token_stream implementation

```
class Token_stream {
   bool full;          // is there a Token in the buffer?
   Token buffer; // here is where we keep a Token put back using putback()
public:
   Token get();                          // get a Token
   void putback(Token);                  // put back a Token
   Token_stream() :full(false), buffer(0) { }        // the buffer starts empty
};

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

Token_stream implementation

```
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

- 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
    - …

Error handling

- The first thing to do once you have a program that "basically works"
- Is to try to "break" it: feeding extreme input in order to find errors
  - Technically this is known as "testing"
  - E.g. this gives an error:
    - -1/2
    - We have to write:
      - (0-1)/2
      - To fix it we must allow the grammar to handle unary minus

```
1+2+3+4+5+6+7+8
1–2–3–4
!+2
;;;
(1+3;
(1+);
1*2/3%4+5–6;
();
1+;
+1
1++;
1/0
1/0;
1++2;
–2;
–2;;;;
1234567890123456;
'a';
q
1+q
1+2; q
```

```
Primary:
    Number
    "(" Expression ")"
```

Error handling: negative numbers

```
Primary:
        Number
        "(" Expression ")"
        "–" Primary
        "+" Primary
```

```
double primary()
{
        Token t = ts.get();
        switch (t.kind) {
        case '(':      // handle '(' expression ')'
                {
                        double d = expression();
                        t = ts.get();
                        if (t.kind != ')') error("')' expected");
                        return d;
                }
        case '8':                       // we use '8' to represent a number
                return t.value;         // return the number's value
        case '–':
                return – primary();
        case '+':
                return primary();
        default:
                error("primary expected");
        }
}
```

Error handling: remainder

- Add % as a Token inside term()
- Convert **double** to **int**
  - so that we can use the % on them

```
case '%':
{       int i1 = narrow_cast<int>(left);
        int i2 = narrow_cast<int>(term());
        if (i2 == 0) error("%: divide by zero");
        left = i1%i2;
        t = ts.get();
        break;
}
```

- int xl = narrow_cast<int>(2.9); //error
- int x2=narrow_cast<int>(2.0); //ok

- narrow_cast<> defined in std_lib_facilities.h
- Note the <> are same as are used for vector<int>

Prompting

- 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!”

- 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

- 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'** (**'8'** what could that mean? Why **'8'**?)
- Once you have cleaned up, let a friend/colleague review the code (“code review”)

Remove “magic constants”

```
// 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”

```
// 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"

```
// 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"

- 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
  - Ever so often, stop adding functionality and “go back” and review code
    - It saves time

Recover from errors

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

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
  - Pre-defined symbolic values
  - Variables
  - Check Chapter 7 in the book to see them implemented

- 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

commenting

- When you go back to your code to clean it up, make sure that the comments you wrote while writing the code are:
  - Still valid (you might have changed the code since the comments)
  - Adequate for another reader (usually they are not except for you)
  - Not so verbose that they distract from the code
- Avoid comments that explain something perfectly clear e.g.:
  - x = b + c; //add b and c and assign the result to x
- Instead write comments for things that code cannot express:
  - E.g. intent (πρόθεση)
    - The code says what it does, not what was intended to do

Next lecture

- In the next two lectures, we'll take a more systematic look at the C++ language features we have used so far. In particular, we need to know more about classes, functions, statements, expressions, and types.

Acknowledgements

Bjarne Stroustrup

Programming -- Principles and Practice Using C++

http://www.stroustrup.com/Programming/

Thank you!

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Ευρωπαϊκό Κοινωνικό Ταμείο
ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ, ΠΟΛΙΤΙΣΜΟΥ & ΑΘΛΗΤΙΣΜΟΥ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης
ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ