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ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ

Εισαγωγή στον Προγραμματισμό
Introduction to Programming

Διάλεξη 5: Σύνταξη προγράμματος

Γ. Παπαγιαννάκης

ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
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επένδυση στην κοινωνία της γνώσης
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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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Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

HY-150 Προγραμματισμός
CS-150 Programming

Lecture 5:
Writing a program

G. Papagiannakis

Abstract

- This lecture and the next describe the process of designing a program through the example of a simple “desk calculator.”

Overview

- Some thoughts on software development
- The idea of a calculator
- Using a grammar
- Expression evaluation
- Program organization

Building a program

- Analysis
  - Refine our understanding of the problem
    - Think of the final use of our program
- Design
  - Create an overall structure for the program
- Implementation
  - Write code
  - Debug
  - Test
- Go through these stages repeatedly

Writing a program: Strategy

- What is the problem to be solved?
  - Is the problem statement clear?
  - Is the problem manageable, given the time, skills, and tools available?
- Try breaking it into manageable parts
  - Do we know of any tools, libraries, etc. that might help?
    - Yes, even this early: **iostream**s, **vector**, etc.
- Build a small, limited version solving a key part of the problem
  - To bring out problems in our understanding, ideas, or tools
  - Possibly change the details of the problem statement to make it manageable
- If that doesn't work
  - Throw away the first version and make another limited version
  - Keep doing that until we find a version that we're happy with
- Build a full scale solution
  - Ideally by using part of our initial version

Writing a program: Example

- I'll build a program in stages, making lot of "typical mistakes" along the way
  - Even experienced programmers make mistakes
    - Lots of mistakes; it's a necessary part of learning
  - Designing a good program is genuinely difficult
  - It's often faster to let the compiler detect gross mistakes than to try to get every detail right the first time
    - Concentrate on the important design choices
  - Building a simple, incomplete version allows us to experiment and get feedback
    - Good programs are "grown"

A simple calculator

- Given expressions as input from the keyboard, evaluate them and write out the resulting value
  - For example
    - Expression: 2+2
    - Result: 4
    - Expression: 2+2*3
    - Result: 8
    - Expression: 2+3-25/5
    - Result: 0
- Let's refine this a bit more …

Pseudo Code

- A first idea:

```
int main()
{
  variables                          // pseudo code
  while (get a line) {                    // what's a line?
   analyze the expression     // what does that mean?
   evaluate the expression
   print the result
  }
}
```

- **H**ow do we represent **45+5/7** as data?
- **H**ow do we find **45 + 5 /** and **7** in an input string?
- How do we make sure that **45+5/7** means **45+(5/7)** rather than **(45+5)/7**?
- Should we allow floating-point numbers (sure!)
- **C**an we have variables? **v=7; m=9; v*m** (later)

A simple calculator

- Wait!
  - We are just about to reinvent the wheel!
  - Read Chapter 6 for more examples of dead-end approaches
- What would the experts do?
  - Computers have been evaluating expressions for 50+ years
  - There *has* to be a solution!
  - What *did* the experts do?
    - Reading is good for you
    - Asking more experienced friends/colleagues can be far more effective, pleasant, and time-effective than slogging along on your own

Expression Grammar

- This is what the experts usually do – write a *grammar*:

Expression :
Term
Expression '+' Term *e.g.*, **1+2**, **(1-2)+3**, **2*3+1**
Expression '-' Term

Term :
Primary
Term '*' Primary *e.g.*, **1*2**, **(1-2)*3.5**
Term '/' Primary
Term '%' Primary

Primary :
Number *e.g.*, **1**, **3.5**
'(' Expression ')' *e.g.*, **(1+2*3)**

Number :
floating-point literal *e.g.*, **3.14**, **0.274e1**, or **42** – as defined for C++

A program is built out of Tokens (*e.g.*, numbers and operators).

A side trip: Grammars

- What's a *grammar*?
  - A set of (syntax) rules for expressions.
  - The rules say how to analyze ("parse") an expression.
  - Some seem hard-wired into our brains
  - Example, you know what this means:
    - **2*3+4/2**
    - **birds fly but fish swim**
  - You know that this is wrong:
    - **2 * + 3 4/2**
    - **fly birds fish but swim**
  - Why is it right/wrong?
  - How do we know?
  - How can we teach what we know to a computer?

Grammars – “English”

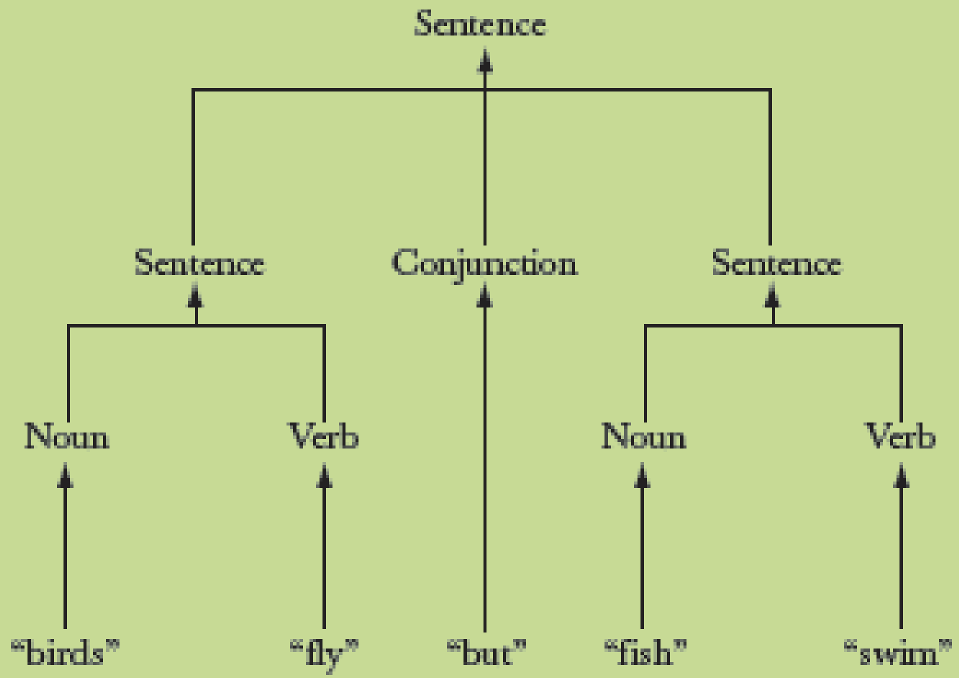
Parsing a simple English sentence

Sentence :
- Noun Verb
- Sentence Conjunction Sentence

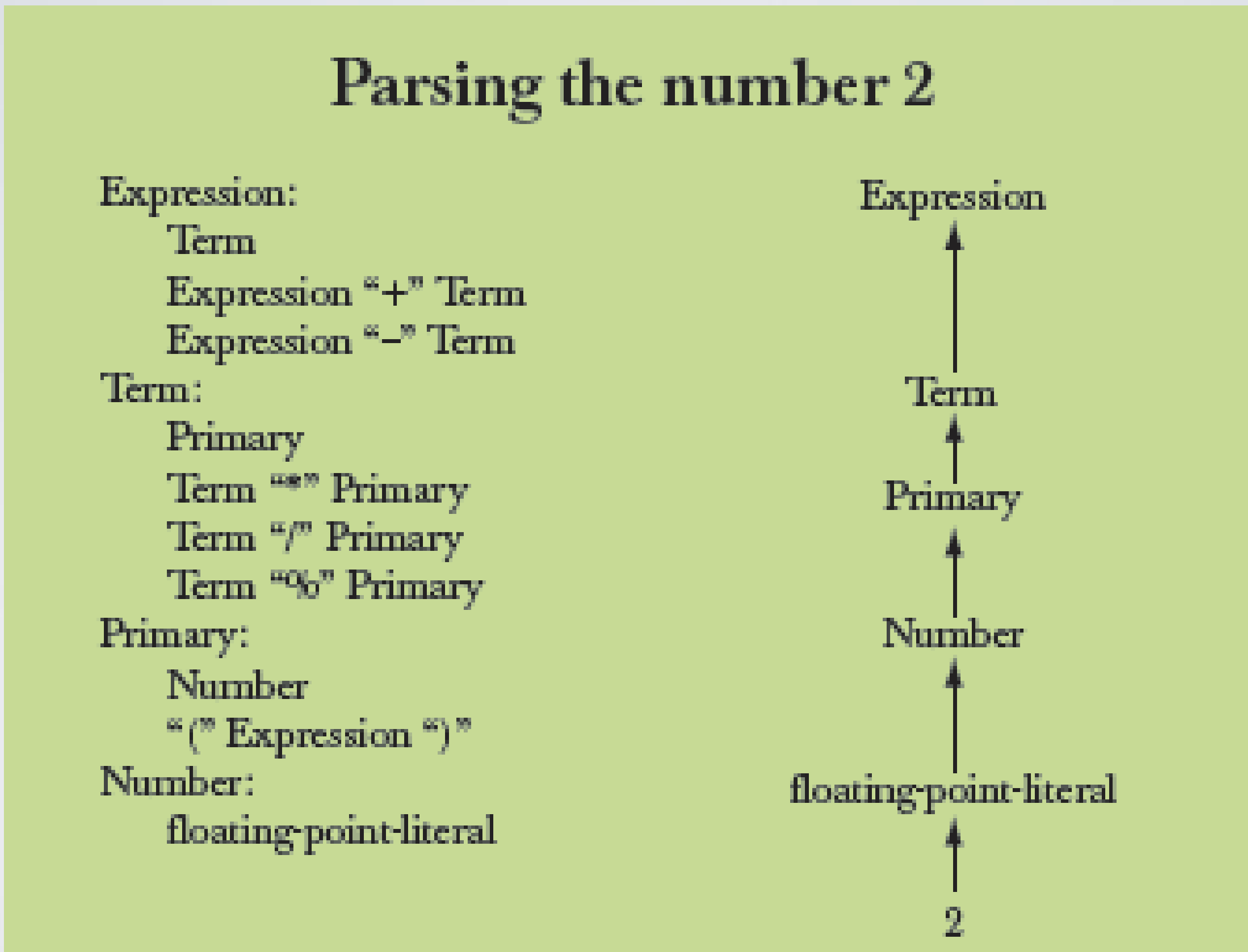
Conjunction :
- “and”
- “or”
- “but”

Noun :
- “birds”
- “fish”
- “C++”

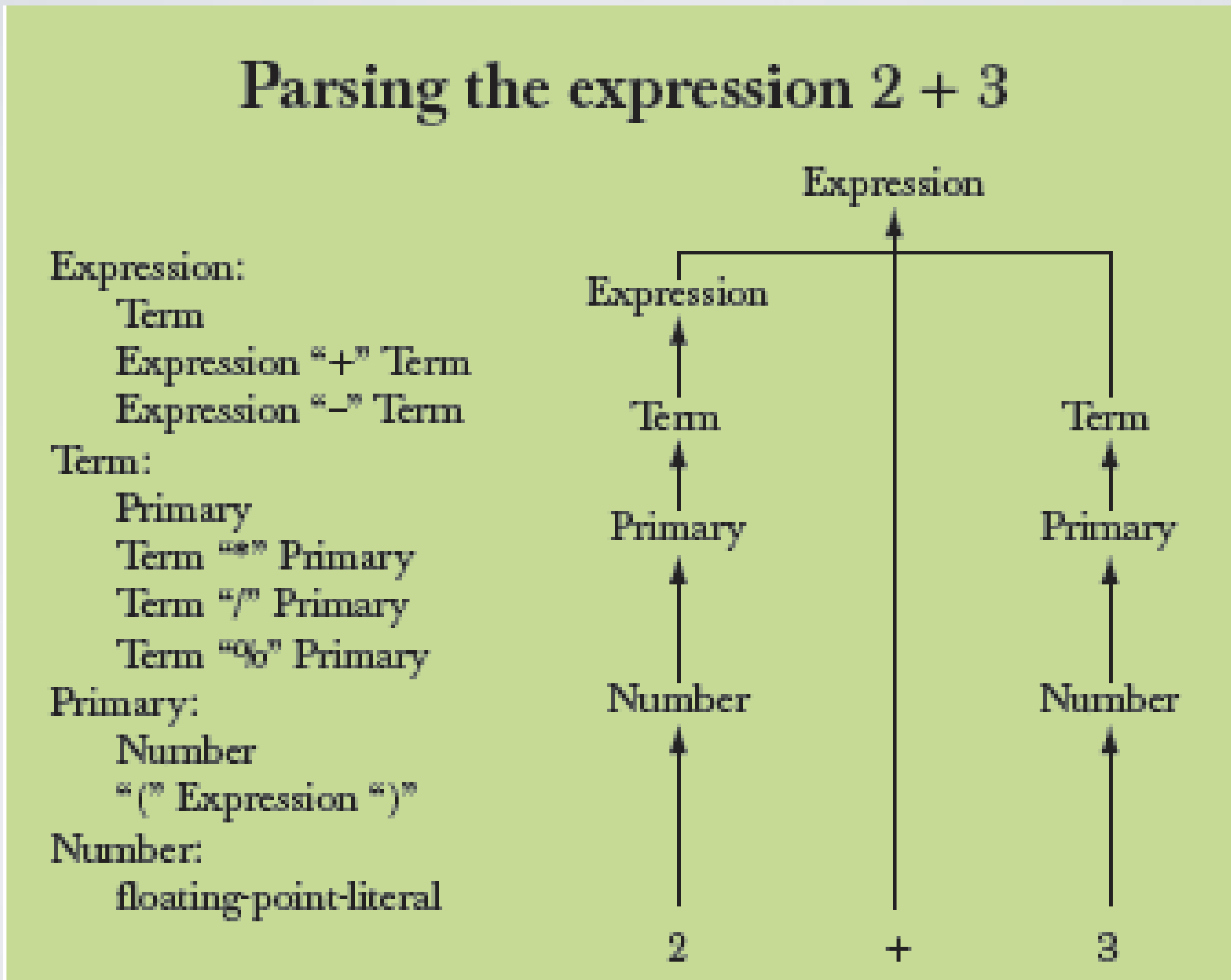
Verb :
- “rules”
- “fly”
- “swim”



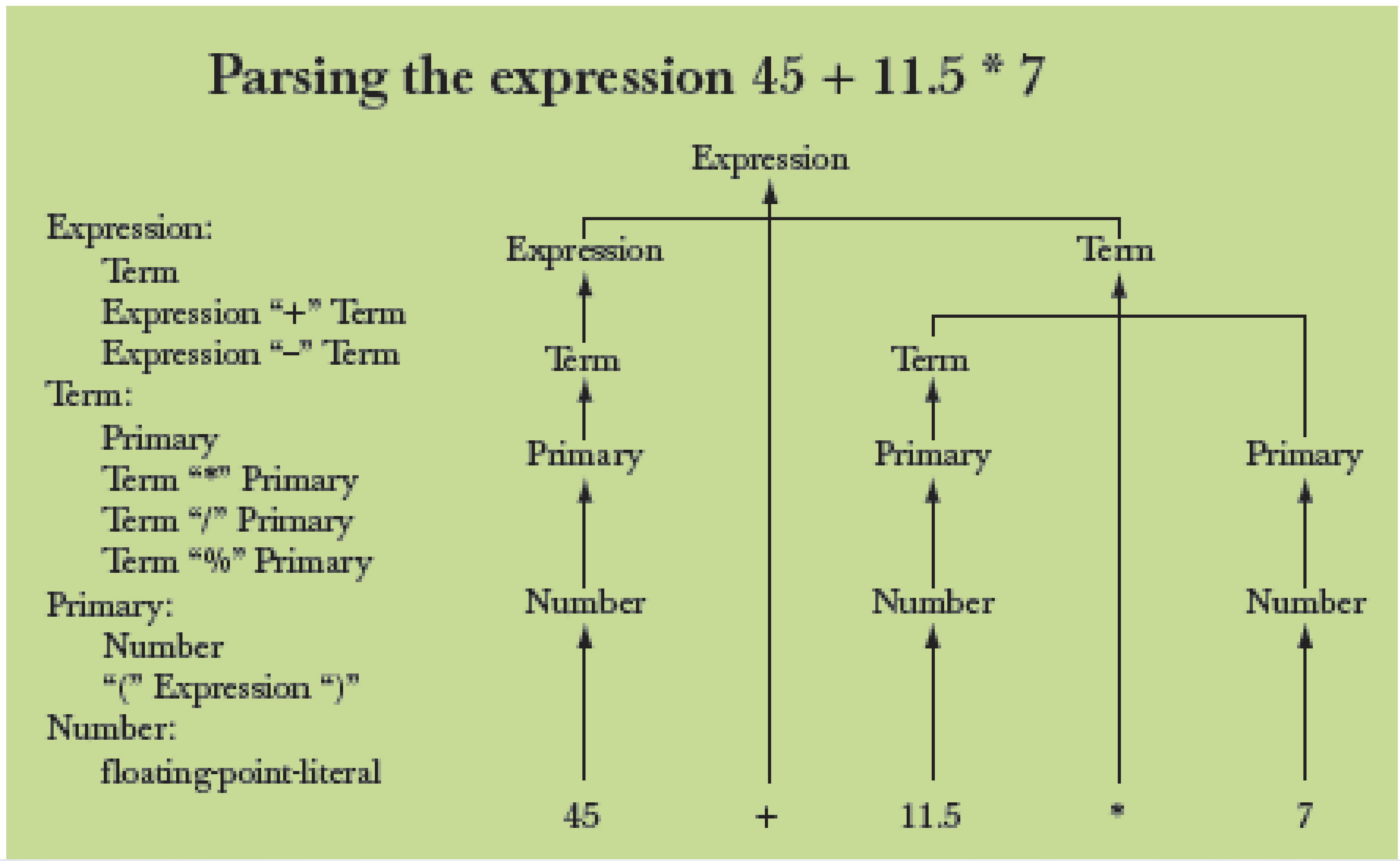
Grammars - expression



Grammars - expression



Grammars - expression



Functions for parsing

We need functions to match the grammar rules

get() *// read characters and compose tokens*
*// calls **cin** for input*

expression() *// deal with + and –*
*// calls **term()** and **get()***

term () *// deal with *, /, and %*
*// calls **primary()** and **get()***

primary() *// deal with numbers and parentheses*
*// calls **expression()** and **get()***

Note: each function deals with a specific part of an expression and leaves everything else to other functions – this radically simplifies each function.

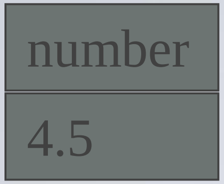
Analogy: a group of people can deal with a complex problem by each person handling only problems in his/her own specialty, leaving the rest for colleagues.

Function Return Types

- What should the parser functions return?
  - How about the result?

```
Token get();              // read characters and compose tokens
double expression();      // deal with + and –
                          //          return the sum (or difference)
double term ();           // deal with *, /, and %
                          //          return the product (or …)
double primary();         // deal with numbers and parentheses
                          //          return the value
```

- What is a **Token**?



What is a token?

- We want to see input as a stream of tokens
  - We read characters **1 + 4*(4.5-6)** (That's 13 characters incl. 2 spaces)
  - 9 tokens in that expression: **1 + 4 * (4.5 - 6)**
  - 6 kinds of tokens in that expression: number **+ * (-)**
- We want each token to have two parts
  - A "kind"; e.g., number
  - A value; e.g., **4**
- We need a type to represent this "Token" idea
  - We'll build that in the next lecture, but for now:
    - **get_token()** gives us the next token from input
    - **t.kind** gives us the kind of the token
    - **t.value** gives us the value of the token

Dealing with + and -

Expression:
  Term
  Expression '+' Term   *// Note: every Expression starts with a Term*
  Expression '-' Term

```
double expression()        // read and evaluate: 1   1+2.5   1+2+3.14  etc.
{
   double left = term();                    // get the Term
   while (true) {
         Token t = get_token();              // get the next token…
         switch (t.kind) {                   // … and do the right thing with it
         case '+':    left += term(); break;
         case '-':    left -= term(); break;
         default:     return left;           // return the value of the expression
         }
   }
}
```

Dealing with *, /, and %

```
double term()     // exactly like expression(), but for *, /, and  %
{
   double left = primary();                         // get the Primary
   while (true) {
             Token t = get_token();                 // get the next Token…
             switch (t.kind) {
             case '*':     left *= primary(); break;
             case '/':     left /= primary(); break;
             case '%':     left %= primary(); break;
             default:      return left;             // return the value
             }
   }
}
```

- Oops: doesn’t compile
  - % isn’t defined for floating-point numbers

Dealing with * and /

Term :

Primary

Term ‘*’ Primary *// Note: every Term starts with a Primary*

Term ‘/’ Primary

```
double term()        // exactly like expression(), but for *, and /
{
    double left = primary();              // get the Primary
    while (true) {
            Token t = get_token();                // get the next Token
            switch (t.kind) {
            case '*':    left *= primary(); break;
            case '/':    left /= primary(); break;
            default:     return left;             // return the value
            }
    }
}
```

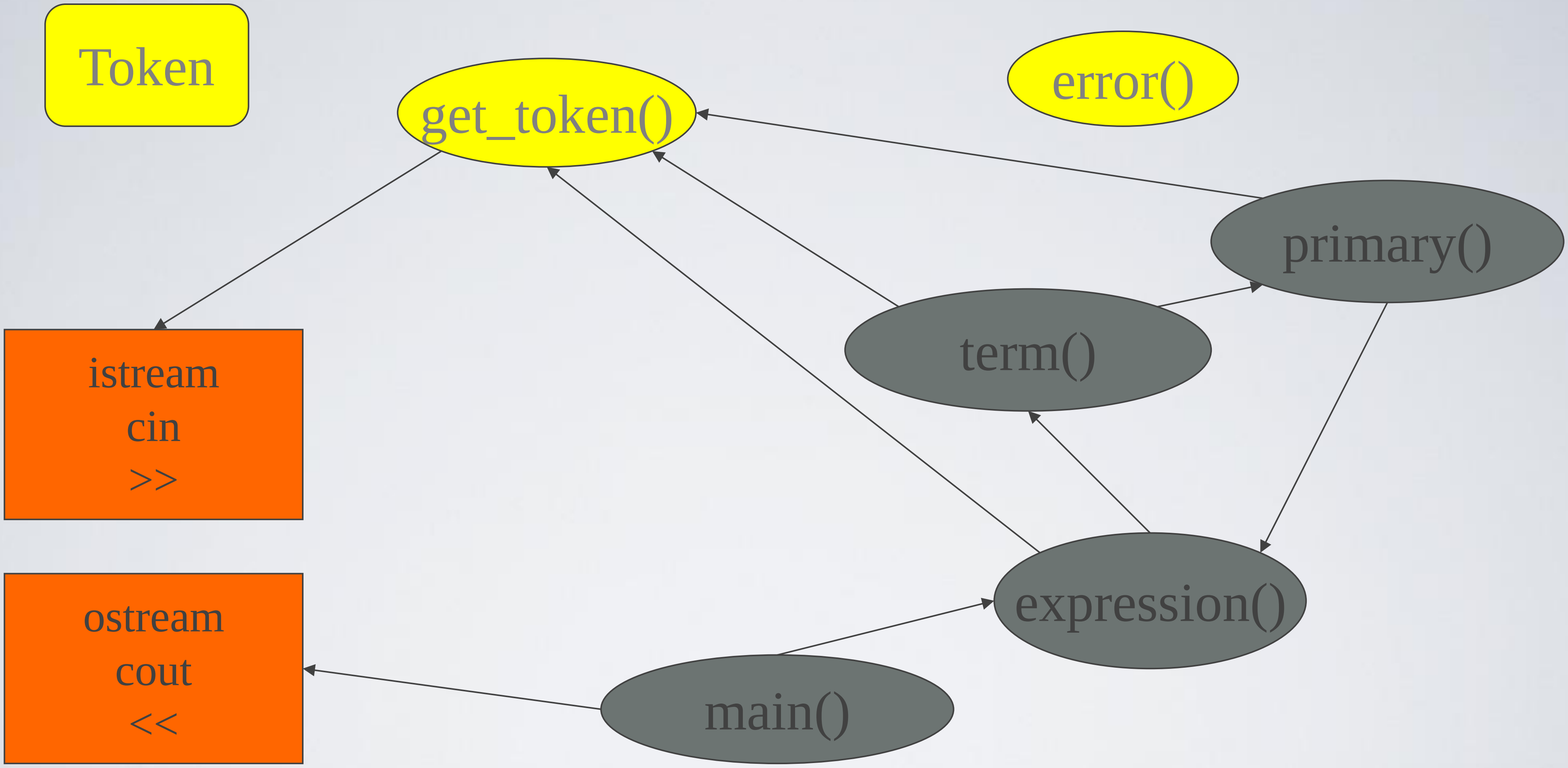
Dealing with divide by 0

```
double term()        // exactly like expression(), but for * and  /
{
    double left = primary();                    // get the Primary
    while (true) {
            Token t = get_token();              // get the next Token
            switch (t.kind) {
            case '*':
                    left *= primary();
                    break;
            case '/':
            {       double d = primary();
                    if  (d==0) error("divide by zero");
                    left /= d;
                    break;
            }
            default:
                    return left;                // return the value
            }
    }
}
```

Dealing with numbers and parentheses

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

Program organization



- Who calls who? (note the loop)

The program

```
#include "std_lib_facilities.h"

// Token stuff (explained in the next lecture)

double expression(); // declaration so that primary() can call      expression()

double primary() { /* … */ }     // deal with numbers and parentheses
double term() { /* … */ }        // deal with * and / (pity about %)
double expression() { /* … */ } // deal with + and –

int main() { /* … */ }           // on next slide
```

```
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
```

The program – main()

```
int main()
try {
   while (cin)
               cout << expression() << '\n';
   keep_window_open();                // for some Windows versions
}
catch (runtime_error& e) {
   cerr << e.what() << endl;
   keep_window_open ();
   return 1;
}
catch (…) {
   cerr << "exception \n";
   keep_window_open ();
   return 2;
}
```

A mystery

• 2	
•	
• 3	
• 4	
• 2	an answer
• 5+6	
• 5	an answer
• X	
• Bad token	an answer (finally, an expected answer)

A mystery

- 1 2 3 4+5 6+7 8+9 10 11 12
- 1 an answer
- 4 an answer
- 6 an answer
- 8 an answer
- 10 an answer

- Aha! Our program "eats" two out of three inputs
  - How come?
  - Let's have a look at expression()

Dealing with + and -

Expression:
  Term
  Expression '+' Term   *// Note: every Expression starts with a Term*
  Expression '-' Term

```
double expression()          // read and evaluate: 1   1+2.5   1+2+3.14  etc.
{
   double left = term();                          // get the Term
   while (true) {
         Token t = get_token();                   // get the next token…
         switch (t.kind) {                        // … and do the right thing with it
         case '+':    left += term(); break;
         case '-':    left -= term(); break;
         default:     return left;                // <<< doesn't use "next token"
         }
   }
}
```

Dealing with + and -

- So, we need a way to "put back" a token!
  - Back into what?
  - "the input," of course; that is, we need an input stream of tokens

```
double expression()        // deal with + and -
{
   double left = term();
   while (true) {
          Token t = ts.get();          // get the next token from a "token stream"
          switch (t.kind) {
          case '+':    left += term(); break;
          case '-':    left -= term(); break;
          default:     ts.putback(t);  // put the unused token back
                       return left;
          }
   }
}
```

Dealing with * and /

- Now make the same change to **term()**

```
double term()          // deal with * and  /
{
    double left = primary();
    while (true) {
            Token t = ts.get();     // get the next Token from input
            switch (t.kind) {
            case '*':
                    // deal with *
            case '/':
                    // deal with /
            default:
                    ts.putback(t);          // put unused token back into input stream
                    return left;
            }
    }
}
```

The program

- It "sort of works"
  - That's not bad for a first try
    - Well, second try
    - Well, really, the fourth try; see the book
  - But "sort of works" is not good enough
  - When the program "sort of works" is when the work (and fun) really start
- Now we can get feedback!

Another mystery

- 2 3 4 2+3 2*3
- 2 an answer
- 3 an answer
- 4 an answer
- 5 an answer

- What! No “6” ?
  - The program looks ahead one token
    - It’s waiting for the user
  - So, we introduce a “print result” command
  - While we’re at it, we also introduce a “quit” command

The main() program

```
int main()
{
   double val = 0;
   while (cin) {
            Token t = ts.get();          // rather than get_token()
            if (t.kind == 'q') break;              // 'q' for "quit"
            if (t.kind == ';')                     // ';' for "print now"
                        cout <<  val << '\n';      // print result
            else
                        ts. putback(t);     // put a token back into the input stream
            val = expression();          // evaluate
   }
   keep_window_open();
}
// … exception handling …
```

Now the calculator is minimally useful

- 2;
- 2 an answer
- 2+3;
- 5 an answer
- 3+4*5;
- 23 an answer
- q

Next lecture

- Completing a program
  - Tokens
  - Recovering from errors
  - Cleaning up the code
  - Code review
  - Testing

For your assignment 1

- Study all the notes so far
- Type-use/Compile/run the provided source code
- Study the book chapters (if you can)

we want to actively discourage:

- (1) design the complete program,
  - write all the code,
  - *then* test it
- (2) just start coding;
  - add features and reorganize as needed;
- ship when it looks good

For your assignment 1

- Understanding the problem you would like your program to solve is key to a good program – after all, a program that solves the wrong problem is of little use, however elegant it may be.
- Analysis – write a description of what should be done – this is called a set of requirements or a specification.
- Design – an overall structure for the system including which parts the implementation should have and how they should communicate with each other.
- Break the problem you want to solve into manageable parts, even the smallest program for solving a real problem is large enough to be subdivided.
- Use pseudo-code in the early stages of design when we are not yet certain exactly what our notation means.

How to pragmatically deal with errors

- Use Lecture 4 notes:
  - C++ exceptions, ways to deal with compile, link and runtime errors
- Study again the notes + reference pages/book
- Use the online library: Google!
  - "your term" filetype:cpp
    - E.g. if(cin) filetype:cpp
- Work together with friends/colleagues
- <u>Post an error report</u> to the online forum, specifying:
  - Platform + Compiler: e.g. g++, Linux
  - Complete part of the source code that the problem occurs, variable declaration, initialization, code fragment that the error occurs etc.
    - Be careful not to disclose the solution to an assignment like that
  - Complete copy of the Compiler/linker/system error messages or warnings

Acknowledgements

Bjarne Stroustrup

Programming -- Principles and Practice Using C++

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

Thank you!

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