構文解析

Parsing

Contents

1. What is Parser ?
2. Method

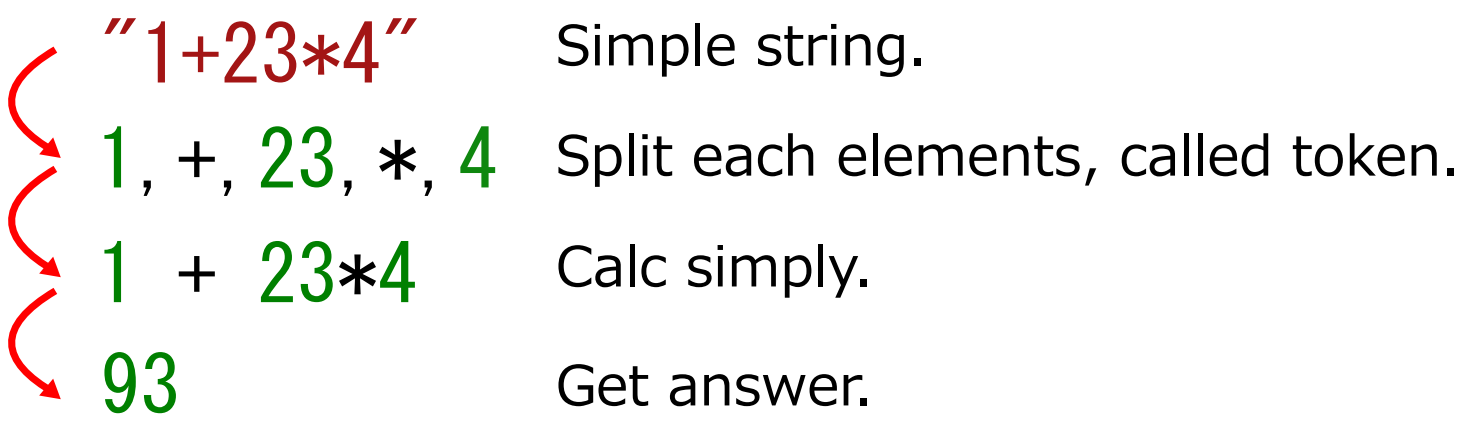
This slide is almost based on 構文解析 Howto.

Once you learn the method of parse, you will understand that **you only do what problems say** in many problems of parsing.

What is parser?

the process of analysing a string of symbols, either in natural language, computer languages or data structures, conforming to the rules of a formal grammar.

Example



- Although the first process is called parser, but in this slide I will call a whole process it.
- Parsing program is called parser.

Parsing on competitive programming

- Top-down parsing is often used on competitive programming.
  - Called Recursive Descent Parsing.
- Usual parsing method saves any tokens as tree, but we don't.

Preparation: Backus-Naur(BNF) form

- Many problem is solved writing BNF.
- BNF is a method to define syntax of languages.
- It has recursive structure.

Example

Definition of expression

$$\langle \text{expr} \rangle := \langle \text{term} \rangle \mid \langle \text{expr} \rangle + \langle \text{expr} \rangle \mid \langle \text{expr} \rangle - \langle \text{expr} \rangle$$

$$\langle \text{term} \rangle := \langle \text{number} \rangle \mid \langle \text{term} \rangle * \langle \text{term} \rangle \mid \langle \text{term} \rangle / \langle \text{term} \rangle$$

$$\langle \text{number} \rangle := 0 \mid 1 \mid 2 \mid 3 \mid 4 \mid 5 \mid 6 \mid 7 \mid 8 \mid 9 \mid \langle \text{number} \rangle \langle \text{number} \rangle$$

More easily

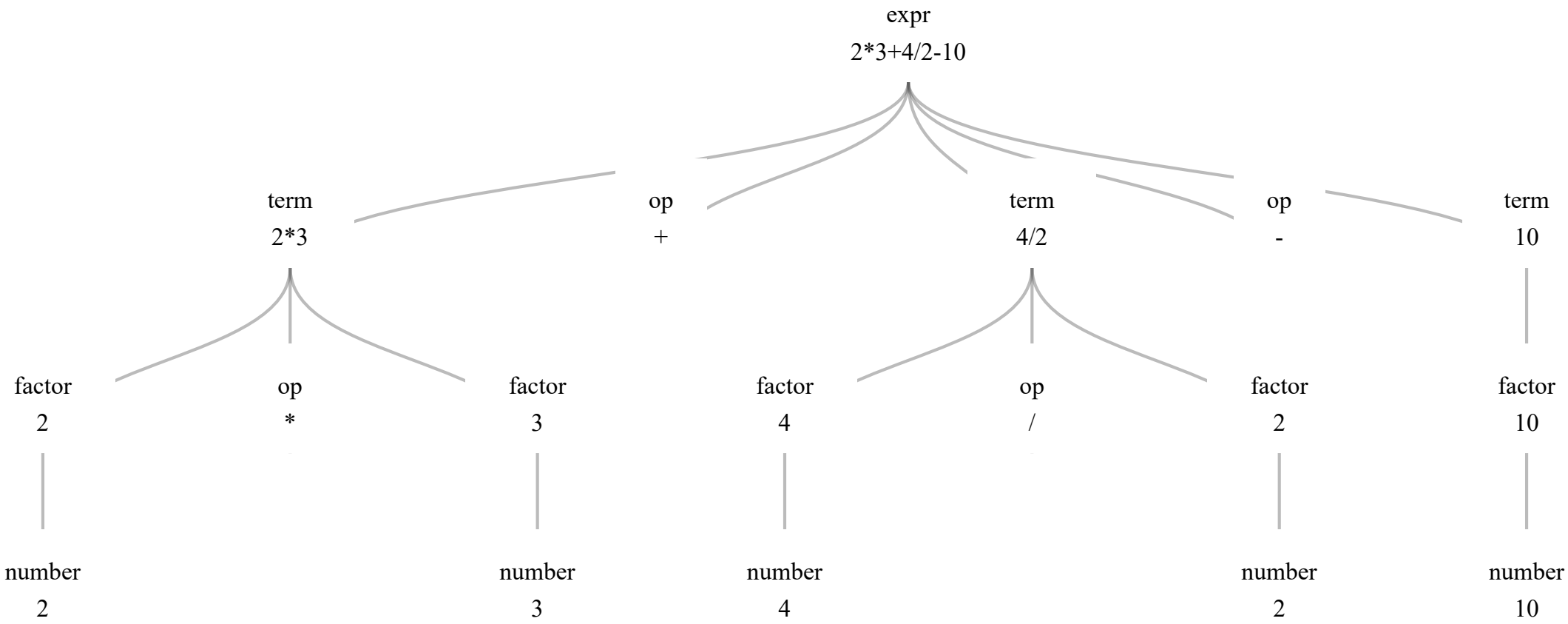
- Strictly speaking, bellow is not rule of BNF. But in this slide I will consider it as BNF, too.
- We don't have to make rule following to BNF completely; **we can solve many problems only making rule like BNF**.

$$\langle \text{expr} \rangle := \langle \text{term} \rangle \ \underline{+ \text{ or } -} \ \langle \text{term} \rangle \ \underline{+ \text{ or } -} \ \cdots$$

$$\langle \text{term} \rangle := \langle \text{number} \rangle \ \underline{* \text{ or } /} \ \langle \text{number} \rangle \ \underline{* \text{ or } /} \ \cdots$$

$$\langle \text{number} \rangle := 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, \ldots$$

Recursive Structure



I want to use parensis!

Add the rule of factor.

$$
\begin{aligned}
\langle \text{expr} \rangle &:= \langle \text{term} \rangle \ \underline{+ \text{ or } -} \ \langle \text{term} \rangle \ \underline{+ \text{ or } -} \ \cdots \\
\langle \text{term} \rangle &:= \langle \text{factor} \rangle \ \underline{* \text{ or } /} \ \langle \text{factor} \rangle \ \underline{* \text{ or } /} \ \cdots \\
\langle \text{factor} \rangle &:= (\langle \text{expr} \rangle) \text{ or } \langle \text{number} \rangle \\
\langle \text{number} \rangle &:= 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, \ldots
\end{aligned}
$$

After definition of BNF

- You only write following BNF!
- But you need practice.

The spell when parsing

It is convenient for you to know:

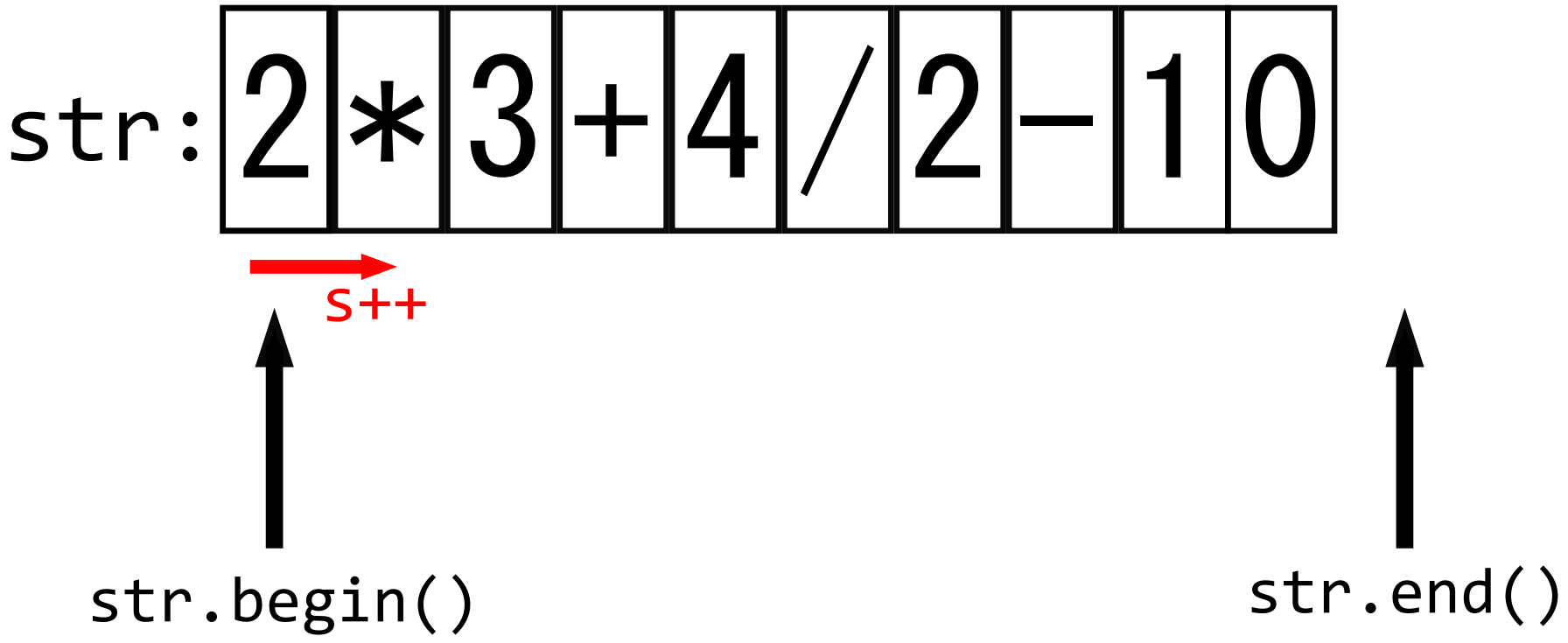
- isdigit(x);
  returns if x is number, defined in ctype.
- string::const_iterator;
  All you have to do is to know it is "type of safe pointer for string".

So you write these at first as a spell.

```
#include <iostream>
#include <string>
#include <ctype.h>

using namespace std;
typedef string::const_iterator State;
```

Supplement: string::const_iterator

```
string::const_iterator s = str.begin()
```



Case study

Given an expression as a string which satisfies this BNF syntax:

$$\begin{aligned}
\langle \text{expr} \rangle &:= \langle \text{term} \rangle \ \underline{+ \text{ or } -} \ \langle \text{term} \rangle \ \underline{+ \text{ or } -} \ \cdots \\
\langle \text{term} \rangle &:= \langle \text{factor} \rangle \ \underline{* \text{ or } /} \ \langle \text{factor} \rangle \ \underline{* \text{ or } /} \ \cdots \\
\langle \text{factor} \rangle &:= (\langle \text{expr} \rangle) \text{ or } \langle \text{number} \rangle \\
\langle \text{number} \rangle &:= 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, \ldots
\end{aligned}$$

Write a program to calculate it and output the answer.

Step

1. Write functions named BNF's left value.
    - They always take an argument reference of State.
    - In the case that each mutually call them, you have to write function prototypes.
2. Fill the procedure to parse.

Step1

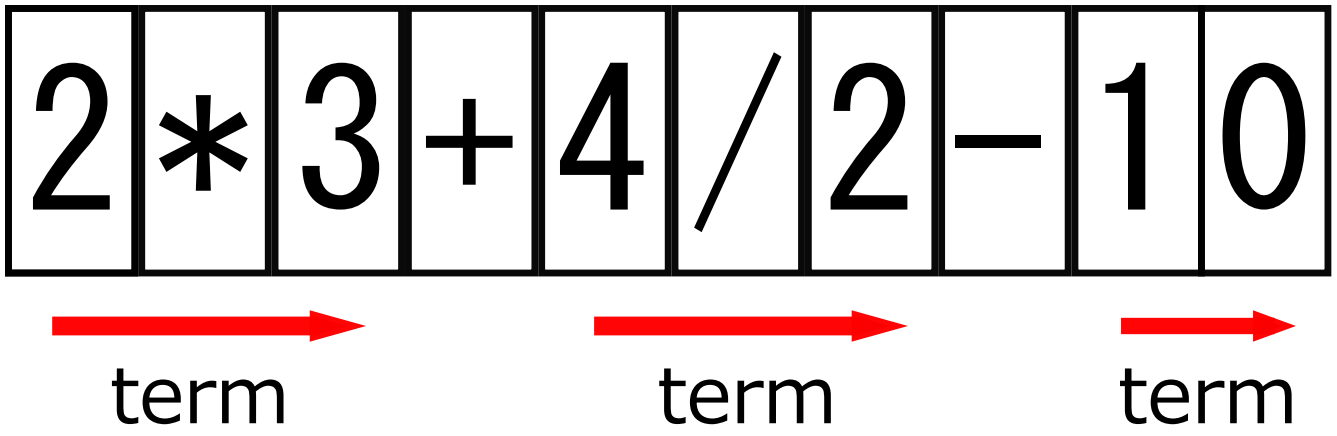
$$\langle \text{expr} \rangle := \cdots$$
$$\langle \text{term} \rangle := \cdots$$
$$\langle \text{factor} \rangle := \cdots$$
$$\langle \text{number} \rangle := \cdots$$

```
int expr(State& s){

}
int term(State& s){

}
int factor(State& s){

}
int num(State& s){

}
```

Step2

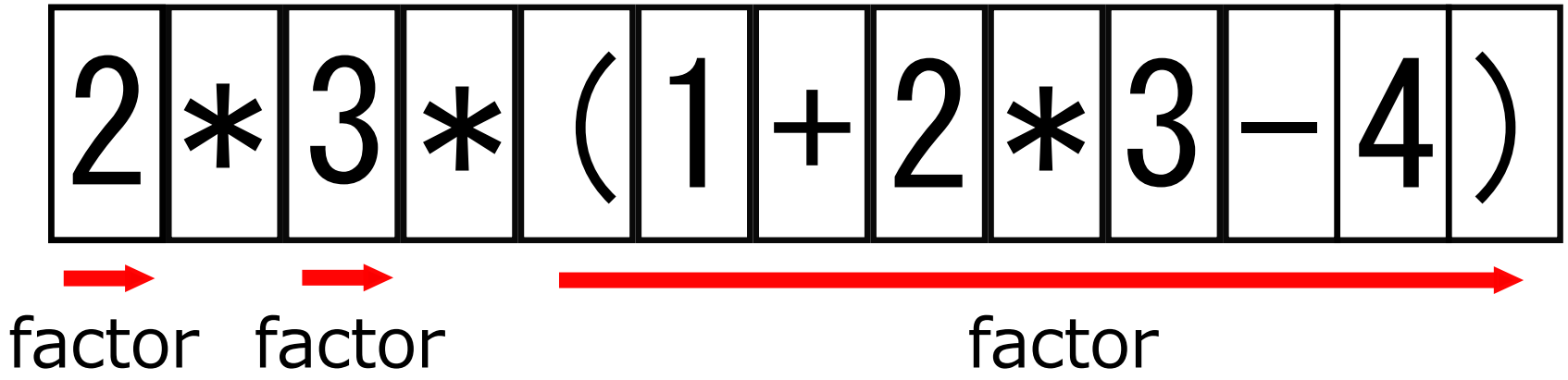
Image concrete example.

$$\langle \text{expr} \rangle := \langle \text{term} \rangle \ \underline{+ \text{ or } -} \ \langle \text{term} \rangle \ \underline{+ \text{ or } -} \ \cdots$$



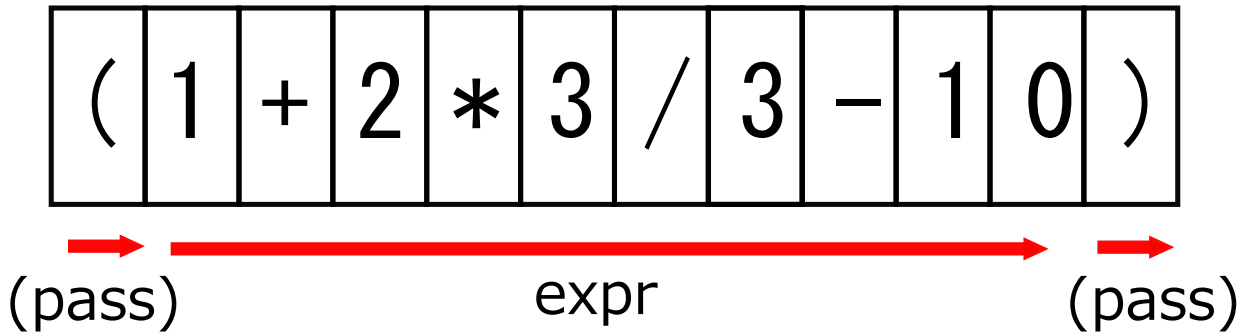
```
int expr(State& s){
  int ret = term(s);
  while(1){
    char op = *s;
    if (op == '+') {
      s++;
      ret += term(s);
    } else if (op == '-') {
      s++;
      ret -= term(s);
    } else {
      break;
    }
  }
  return ret;
}
```

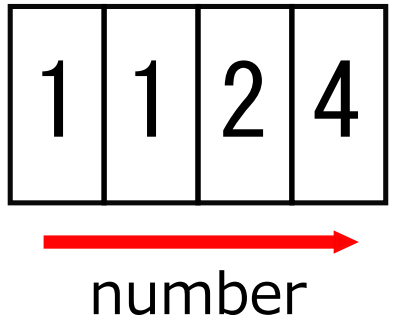
$$\langle \text{term} \rangle := \langle \text{factor} \rangle \ \underline{* \text{ or } /} \ \langle \text{factor} \rangle \ \underline{* \text{ or } /} \ \cdots$$



```
int term(State& s) {
  int ret = factor(s);
  while (1) {
    char op = *s;
    if (op == '*') {
      s++;
      ret *= factor(s);
    } else if (op == '/'){
      s++;
      ret /= factor(s);
    } else {
      break;
    }
  }
  return ret;
}
```

$$\langle \text{factor} \rangle := (\langle \text{expr} \rangle) \text{ or } \langle \text{number} \rangle$$





```
int factor(State& s) {
  if (*s == '(') {
    s++;
    int ret = expr(s);
    s++;
    return ret;
  } else {
    return number(s);
  }
}
```

$$\langle \text{number} \rangle := 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, \ldots$$

```
int number(State& s) {
  int ret = 0;
  while(isdigit(*s)) {
    ret *= 10;
    ret += *s - '0';
    s++;
  }
  return ret;
}
```

Add variable - an alphabetical character

```
int vars[i];
// vars[i] := value of variable named i-th alphabet
```

$$\langle \text{factor} \rangle := (\langle \text{expr} \rangle) \text{ , } \langle \text{number} \rangle \text{ ,or } \langle \text{var} \rangle$$

$$\langle \text{var} \rangle := a, b, \ldots, \text{or } z$$

```
int factor(State& s) {
  if (*s == '(') {
    s++;
    int ret = expr(s);
    s++;
    return ret;
  } else if(isdigit(*s)){
    return number(s);
  } else {
    return var(s);
  }
}

int var(State& s) {
  int ret = vars[*s - 'a'];
  s++;
  return ret;
}
```

Add varlabl - alphabetical string

```
map<string,int> vars;
// vars[str] := value of variable named str.
```

$$\langle \text{factor} \rangle := (\langle \text{expr} \rangle) \text{ , } \langle \text{number} \rangle \text{ ,or } \langle \text{var} \rangle$$

$$\langle \text{var} \rangle := \text{string made of lower cases}$$

```
int factor(State& s) {
  if (*s == '(') {
    s++;
    int ret = expr(s);
    s++;
    return ret;
  } else if(isdigit(*s)){
    return number(s);
  } else {
    return var(s);
  }
}

int var(State& s) {
  string str = "";
  while ('a' <= *s && *s <= 'z') {
    str += *s;
    s++;
  }
  return vars[str];
}
```

How to use

```
int main()
{
  string str;
  cin >> str;
  State s = str.begin();
  cout << expr(s) << endl;
  return 0;
}
```

Can we solve all parsing problems?

- Many grammer around the world is very complex.
  - The method we saw in this slide only solve the class of grammer; LL(1)
- But there are little problems except LL(1) in competitive programming.

Sammary

- Parsing is not difficult.
- But you have to remember the way to parsing.

Reference

構文解析HowTo

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再帰下降型構文解析(LL(1))

Exercise

- AOJ0109 Smart Calculator
  English Version
  It is quite same as the case study in this slide.
- AOJ1155 How can I satisfy thee? Let me count the ways...
  English Version