cilly_grammar

词法规范

标识符

```
identifier ::= identifier-nondigit
             | identifier identifier-nondigit
             | identifier digit;
```

其中, `identifier-nondigit` 为下划线, 小写英文字母或大写英文字母; `digit` 为数字 0 到 9.

数值常量

```
integer-const       ::= decimal-const
                      | octal-const
                      | hexadecimal-const;
decimal-const       ::= nonzero-digit
                      | decimal-const digit;
octal-const         ::= "0"
                      | octal-const octal-digit;
hexadecimal-const   ::= hexadecimal-prefix hexadecimal-digit
                      | hexadecimal-const hexadecimal-digit;
hexadecimal-prefix  ::= "0x" | "0X";
```

其中, `nonzero-digit` 为数字 1 到 9; `octal-digit` 为数字 0 到 7; `hexadecimal-digit` 为数字 0 到 9, 或大写/小写字母 a 到 f.

语法规范

```
CompUnit        ::= [CompUnit] (FuncDef | Decl);

Decl            ::= ValDecl | VarDecl;

ValDecl         ::= "val" IDENT ":" BType "=" InitVal ";";
VarDecl         ::= "var" IDENT ":" BType "=" InitVal ";";
InitVal         ::= Exp;

FuncDef         ::= FuncType IDENT "(" [FuncFParams] ")" ["->" BType] Block;
FuncFParams     ::= FuncFParam {"," FuncFParam};
FuncFParam      ::= IDENT ":" BType;
FuncRParams     ::= Exp {"," Exp};
BType           ::= "i32";

Block           ::= "{" {BlockItem} "}";
BlockItem       ::= Decl | Stmt;
Stmt            ::= LVal "=" Exp ";"
                | Block
                | [Exp] ";"
                | "return" [Exp] ";";
                | "if" "(" Exp ")" Stmt ["else" Stmt]
                | "while" "(" Exp ")" Stmt
```

```
                | "continue"
                | "break"
                | FuncDef;

LVal            ::= IDENT;

Exp             ::= LOrExp;
PrimaryExp      ::= "(" Exp ")" | Number | LVal;
Number          ::= INT_CONST;
UnaryExp        ::= PrimaryExp
                  | UnaryOp UnaryExp
                  | IDENT "(" [FuncRParams] ")";
UnaryOp         ::= "+" | "-" | "!";
MulExp          ::= UnaryExp | MulExp ("*" | "/" | "%") UnaryExp;
AddExp          ::= MulExp | AddExp ("+" | "-") MulExp;
RelExp          ::= AddExp | RelExp ("<" | ">" | "<=" | ">=") AddExp;
EqExp           ::= RelExp | EqExp ("==" | "!=") RelExp;
LAndExp         ::= EqExp | LAndExp "&&" EqExp;
LOrExp          ::= LAndExp | LOrExp "||" LAndExp;
```

AST 样例

测试代码

```
fn fact(n: i32) -> i32 {
    if(n == 0) return 1;
    return n * fact(n - 1);
}

fn feb(n: i32) -> i32 {
    if(n < 2) {
        return 1;
    } else {
        return feb(n - 1) + feb(n - 2);
    }
}

fn while_test() -> i32 {
    var n: i32 = 0;
    while(n < 10) {
        print(n);
        n = n + 1;
    }
    return n;
}

fn add(a: i32, b: i32) -> i32 {
    return a + b;
}

fn main () {
    while_test();
    val n: i32 = getint();
    val res: i32 = fact(n);
```

```
    print(res);

    val m: i32 = getint();
    print(feb(m));
}
```

AST

CompUnit { globaldefs: [FuncDef(FuncDef { ident: "fact", btype: Some(I32), funcfparams: Some(FuncFParams { params: [FuncFParam { ident: "n", btype: I32 }] }), block: Block { items: [Stmt(If { condition: Exp { lor_exp: And(Eq(Eq(Rel(Add(Mul(Unary(Pri(LVal(LVal { ident: "n" }))))))), Eq, Add(Mul(Unary(Pri(Number(0)))))))) }, then_branch: Ret(Some(Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(Pri(Number(1)))))))) })), else_branch: None }), Stmt(Ret(Some(Exp { lor_exp: And(Eq(Rel(Add(Mul(Mul(Unary(Pri(LVal(LVal { ident: "n" }))))), Mul, FuncCall { ident: "fact", funcrparams: Some(FuncRParams { exps: [Exp { lor_exp: And(Eq(Rel(Add(Add(Mul(Unary(Pri(LVal(LVal { ident: "n" }))))), Sub, Unary(Pri(Number(1)))))))) }] }) }))))))) })))] } }), FuncDef(FuncDef { ident: "feb", btype: Some(I32), funcfparams: Some(FuncFParams { params: [FuncFParam { ident: "n", btype: I32 }] }), block: Block { items: [Stmt(If { condition: Exp { lor_exp: And(Eq(Rel(Rel(Add(Mul(Unary(Pri(LVal(LVal { ident: "n" }))))))), Lt, Mul(Unary(Pri(Number(2)))))))) }, then_branch: Block(Block { items: [Stmt(Ret(Some(Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(Pri(Number(1)))))))) }))))] }), else_branch: Some(Block(Block { items: [Stmt(Ret(Some(Exp { lor_exp: And(Eq(Rel(Add(Add(Mul(Unary(FuncCall { ident: "feb", funcrparams: Some(FuncRParams { exps: [Exp { lor_exp: And(Eq(Rel(Add(Add(Mul(Unary(Pri(LVal(LVal { ident: "n" }))))), Sub, Unary(Pri(Number(1)))))))) }] }) })), Add, Unary(FuncCall { ident: "feb", funcrparams: Some(FuncRParams { exps: [Exp { lor_exp: And(Eq(Rel(Add(Add(Mul(Unary(Pri(LVal(LVal { ident: "n" }))))), Sub, Unary(Pri(Number(2)))))))) }] }) }))))))) }))))] }) })] } }), FuncDef(FuncDef { ident: "while_test", btype: Some(I32), funcfparams: None, block: Block { items: [Decl(VarDecl(VarDecl { ident: "n", btype: I32, initval: InitVal { exp: Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(Pri(Number(0)))))))) } } })), Stmt(While { condition: Exp { lor_exp: And(Eq(Rel(Rel(Add(Mul(Unary(Pri(LVal(LVal { ident: "n" }))))))), Lt, Mul(Unary(Pri(Number(10)))))))) }, loopbody: Block(Block { items: [Stmt(Exp(Some(Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(FuncCall { ident: "print", funcrparams: Some(FuncRParams { exps: [Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(Pri(LVal(LVal { ident: "n" }))))))))) }] }) }))))))) })))), Stmt(Assign(LVal { ident: "n" }, Exp { lor_exp: And(Eq(Rel(Add(Add(Mul(Unary(Pri(LVal(LVal { ident: "n" }))))), Add, Unary(Pri(Number(1)))))))) }))] }) }), Stmt(Ret(Some(Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(Pri(LVal(LVal { ident: "n" }))))))))) }))))] } }), FuncDef(FuncDef { ident: "add", btype: Some(I32), funcfparams: Some(FuncFParams { params: [FuncFParam { ident: "a", btype: I32 }, FuncFParam { ident: "b", btype: I32 }] }), block: Block { items: [Stmt(Ret(Some(Exp { lor_exp: And(Eq(Rel(Add(Add(Mul(Unary(Pri(LVal(LVal { ident: "a" }))))), Add, Unary(Pri(LVal(LVal { ident: "b" }))))))))) }))))] } }), FuncDef(FuncDef { ident: "main", btype: None, funcfparams: None, block: Block { items: [Stmt(Exp(Some(Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(FuncCall { ident: "print", funcrparams: Some(FuncRParams { exps: [Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(FuncCall { ident: "add", funcrparams: Some(FuncRParams { exps: [Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(Pri(Number(100)))))))) }, Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(Pri(Number(100)))))))) }] }) }))))))) }))))), Stmt(Exp(Some(Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(FuncCall { ident: "while_test", funcrparams: None }))))))) })))), Decl(ValDecl(ValDecl { ident: "n", btype: I32, initval: InitVal { exp: Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(FuncCall { ident: "getint", funcrparams: None }))))))) } } })), Decl(ValDecl(ValDecl { ident: "res", btype: I32, initval: InitVal { exp: Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(FuncCall { ident: "fact", funcrparams: Some(FuncRParams { exps: [Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(Pri(LVal(LVal { ident: "n" }))))))))) }] }) }))))))) } } })), Stmt(Exp(Some(Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(FuncCall { ident: "print", funcrparams:

Some(FuncRParams { exps: [Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(Pri(LVal(LVal { ident: "res" }))))))) }] }) }))))))) }))), Decl(ValDecl(ValDecl { ident: "m", btype: I32, initval: InitVal { exp: Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(FuncCall { ident: "getint", funcrparams: None }))))))) } } })), Stmt(Exp(Some(Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(FuncCall { ident: "print", funcrparams: Some(FuncRParams { exps: [Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(FuncCall { ident: "feb", funcrparams: Some(FuncRParams { exps: [Exp { lor_exp: And(Eq(Rel(Add(Mul(Unary(Pri(LVal(LVal { ident: "m" }))))))))) }] }) }))))))) }] }) }))))))) }))))] } })] }

解释器结果

input

```
10
10
```

output

```
200
0
1
2
3
4
5
6
7
8
9
3628800
89
```

虚拟机字节码表

```
LoadConst(i32),              1      加载一个常数到栈顶。
LoadTrue,                    2      加载True到栈顶。
LoadFalse,                   3      加载False到栈顶。
LoadNull,                    4      加载NULL到栈顶。
LoadGlobal(usize),           5      从全局变量中加载一个变量到栈顶。
StoreGlobal(usize),          6      将栈顶的值储存到全局变量表中。

BinOpAdd,                    100    栈顶两个值相加。
BinOpSub,                    101    栈顶两个值相减。
BinOpMul,                    102    栈顶两个值相乘。
BinOpDiv,                    103    栈顶两个值相除。
BinOpGt,                     104    比较栈顶两个值，大于则结果为true。
BinOpGe,                     105    比较栈顶两个值，大于等于则结果为true。
BinOpLt,                     106    比较栈顶两个值，小于则结果为true。
BinOpLe,                     107    比较栈顶两个值，小于等于则结果为true。
BinOpEq,                     108    比较栈顶两个值，相等则结果为true。
BinOpNe,                     109    比较栈顶两个值，不相等则结果为true。
BinOpOr,                     110    栈顶两个值或。
BinOpAnd,                    111    栈顶两个值与。
// 跳转的地址
Jmp(usize),                  10     无条件跳转到指定位置。
```

```
JmpTrue(usize),              11      如果栈顶值为true，跳转到指定位置。
JmpFalse(usize),             12      如果栈顶值为false，跳转到指定位置。

PrintItem,                   13      打印栈顶的值。
PrintNewline,                14      打印一个换行符。
GetInt,                      15      输入一个整数
Pop,                         16      弹出栈顶值
UniOpNot,                    17      对栈顶的布尔值取反。
UniOpNeg,                    18      对栈顶的值取负。
StorePC,                     19      存储当前 PC。
LoadPC,                      20      从 PC 栈中加载。
// dep, pos
StoreVar(usize, usize),      21      将栈顶的值存储到局部变量表中。
// dep, pos
LoadVar(usize, usize),       22      从局部变量表中加载一个变量到栈顶。
// args个数
EnterScope(usize),           23      进入一个新的作用域。
LeaveScope,                  24      离开当前作用域。
MakeClosure,                 25      创建一个闭包。
// pc_addr, args个数
Call(usize, usize),          26      调用一个函数。
Ret,                         27      从当前函数返回。
```

测试样例生成的字节码

```
0       Call(58, 0)
1       EnterScope(0)
2       LoadVar(1, 0)
3       LoadConst(0)
4       BinOpEq
5       JmpFalse(8)
6       LoadConst(1)
7       Ret
8       LoadVar(1, 0)
9       LoadVar(1, 0)
10      LoadConst(1)
11      BinOpSub
12      Call(1, 1)
13      BinOpMul
14      Ret
15      LeaveScope
16      EnterScope(0)
17      LoadVar(1, 0)
18      LoadConst(2)
19      BinOpLt
20      JmpFalse(23)
21      LoadConst(1)
22      Ret
23      LoadVar(1, 0)
24      LoadConst(1)
25      BinOpSub
26      Call(16, 1)
27      LoadVar(1, 0)
28      LoadConst(2)
29      BinOpSub
```

```
30      Call(16, 1)
31      BinOpAdd
32      Ret
33      LeaveScope
34      EnterScope(0)
35      LoadConst(0)
36      StoreVar(0, 0)
37      LoadVar(0, 0)
38      LoadConst(10)
39      BinOpLt
40      JmpFalse(49)
41      LoadVar(0, 0)
42      PrintItem
43      PrintNewline
44      LoadVar(0, 0)
45      LoadConst(1)
46      BinOpAdd
47      StoreVar(0, 0)
48      Jmp(37)
49      LoadVar(0, 0)
50      Ret
51      LeaveScope
52      EnterScope(0)
53      LoadVar(1, 0)
54      LoadVar(1, 1)
55      BinOpAdd
56      Ret
57      LeaveScope
58      EnterScope(0)
59      Call(34, 0)
60      GetInt
61      StoreVar(0, 0)
62      LoadVar(0, 0)
63      Call(1, 1)
64      StoreVar(0, 1)
65      LoadVar(0, 1)
66      PrintItem
67      PrintNewline
68      GetInt
69      StoreVar(0, 2)
70      LoadVar(0, 2)
71      Call(16, 1)
72      PrintItem
73      PrintNewline
74      LeaveScope
```

> 26 58 0 23 0 22 1 0 1 0 108 12 8 1 1 27 22 1 0 22 1 0 1 1 101 26 1 1 102 27 24 23 0 22 1 0 1 2 106 12 23 1 1 27 22 1 0 1 1 101 26 16 1 22 1 0 1 2 101 26 16 1 100 27 24 23 0 1 0 21 0 0 22 0 0 1 10 106 12 49 22 0 0 13 14 22 0 0 1 1 100 21 0 0 10 37 22 0 0 27 24 23 0 22 1 0 22 1 1 100 27 24 23 0 26 34 0 15 21 0 0 22 0 0 26 1 1 21 0 1 22 0 1 13 14 15 21 0 2 22 0 2 26 16 1 13 14 24

虚拟机运行结果

input

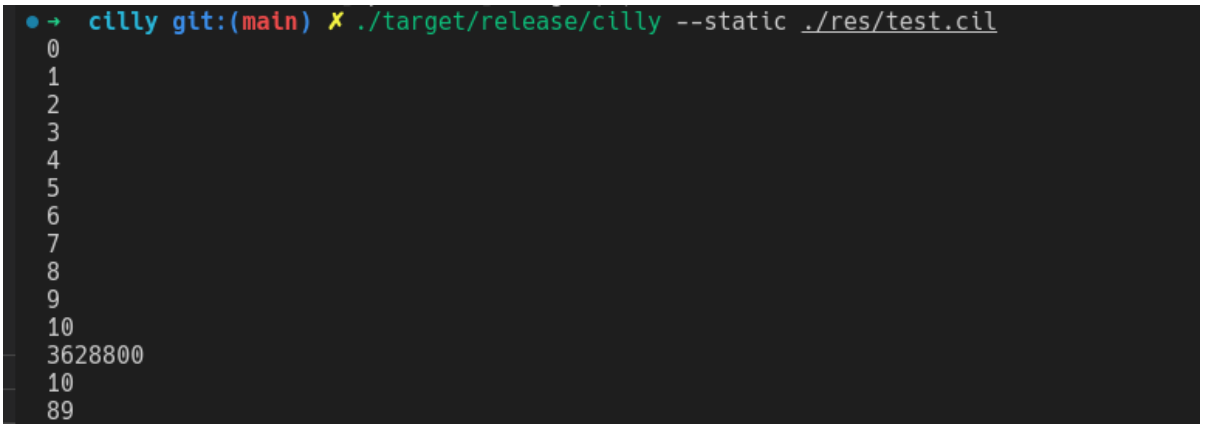
```
10
10
```

output

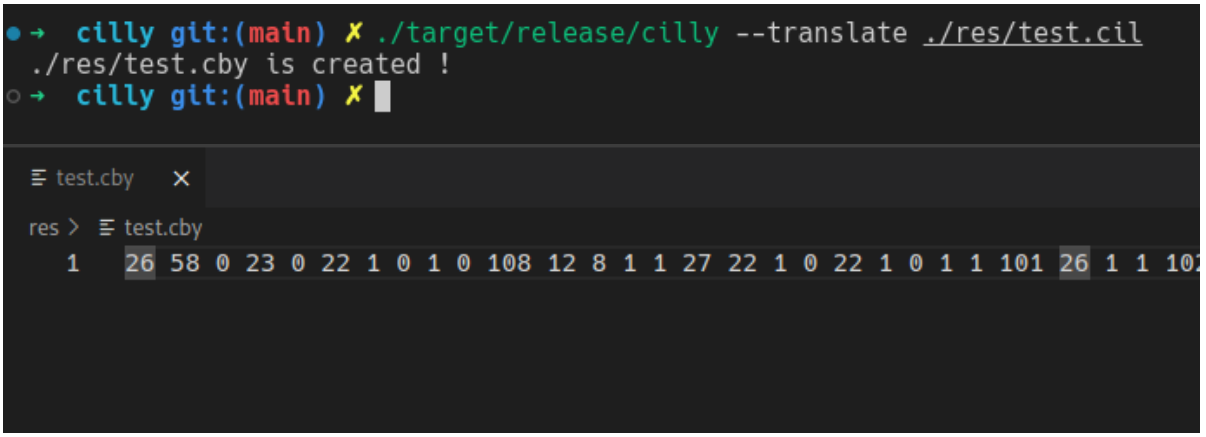
```
0
1
2
3
4
5
6
7
8
9
3628800
89
```

过程截图：

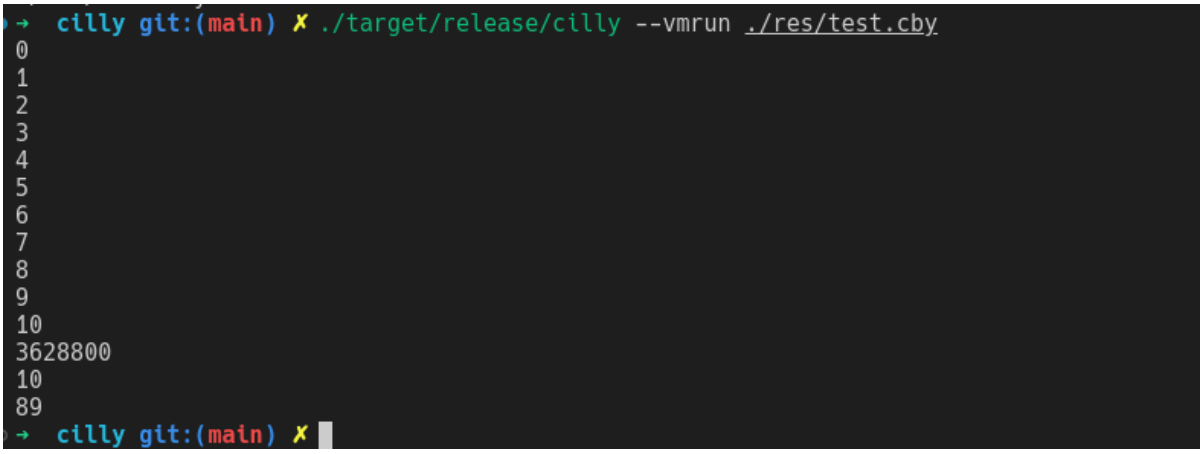
解释器



转化成字节码



虚拟机运行字节码


cilly git:(main) ✗ ./target/release/cilly --vmrun ./res/test.cby
0
1
2
3
4
5
6
7
8
9
10
3628800
10
89
cilly git:(main) ✗