

# Project 3

## Semantic Analysis

Virtual Machine & Optimization Laboratory  
Dept. of Electrical and Computer Engineering  
Seoul National University

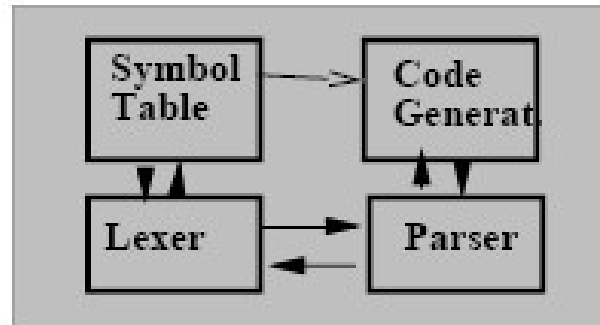


# Projects

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1. Lexical analyzer
2. Yacc programming
- 3. Semantic analysis**
4. Code generation

# Phase Ordering of Compiler Front-Ends



## Lexical analysis (lexer)

- Break input string into “words” (lexeme) called *tokens*

Project 1

## Syntactic analysis (parser)

- Recover structure from the text and put it in a *parse tree*

Project 2

## Semantic Analysis

- Discover “meaning” (e.g., type-checking)
- Prepare for code generation
- Works with a *symbol table*

Project 3

# Project 3

## > Project 3

- Semantic Analysis를 통해 Semantic Error 체크 및 에러 메시지 출력

### Example

```
int main() {  
    int a;  
    a = 5;        // Syntactic : OK. Semantic : OK  
    a = 'a';      // Syntactic : OK. Semantic : Error => Print message  
}
```

## > TODO

- 수업시간에 배운 내용을 토대로 **Scoped Symbol Table** 구현 **CH8 ppt**
- subc.y 문법의 각 terminal과 nonterminal 사이 적절한 위치에 action(C코드)을 삽입해서 Symbol Table을 이용해 **Semantic Error** 체크 **Project3\_slides.pdf**
- 에러가 발견될 경우 **메시지 출력** **project3.pdf**



# **SEMANTIC CHECK**

# Semantic Check

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- Undeclared Variables & Functions
- Re-declaration
- Type Checking
- Structure & Structure pointer Declaration
- Function Declaration

# Undeclared Variables & Functions

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## Defining variables or function call which is not declared makes error

\*Implicit declaration, recursive functions & structs 은 존재하지 않는다고 가정

### ➤ variable (undeclared)

```
// int a;  
a = 0;    /* error: use of undeclared identifier */
```

### ➤ variable (out of scope)

```
{ int a; }  
a = 0;    /* error: use of undeclared identifier */
```

### ➤ function call (undeclared)

```
// void foo();  
foo();    /* error: use of undeclared identifier */
```

# Re-declaration

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## Re-declaration of variable, struct, function makes error

- \* Forward declaration, function overloading은 없다고 가정
- \* Variable, Struct, Function 등 서로 다른 종류끼리 이름이 겹치는 경우는 고려하지 않음

```
{
    int a;
    int a;      /* error: redeclaration */
    char a;     /* error: redeclaration */
}
{
    int a;
    {
        int a; /* OK */
    }
}
```



# Type Checking (Assignment Operation)

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## Assignment Operation Semantic Check

다음과 같은 순서로 Semantic Check

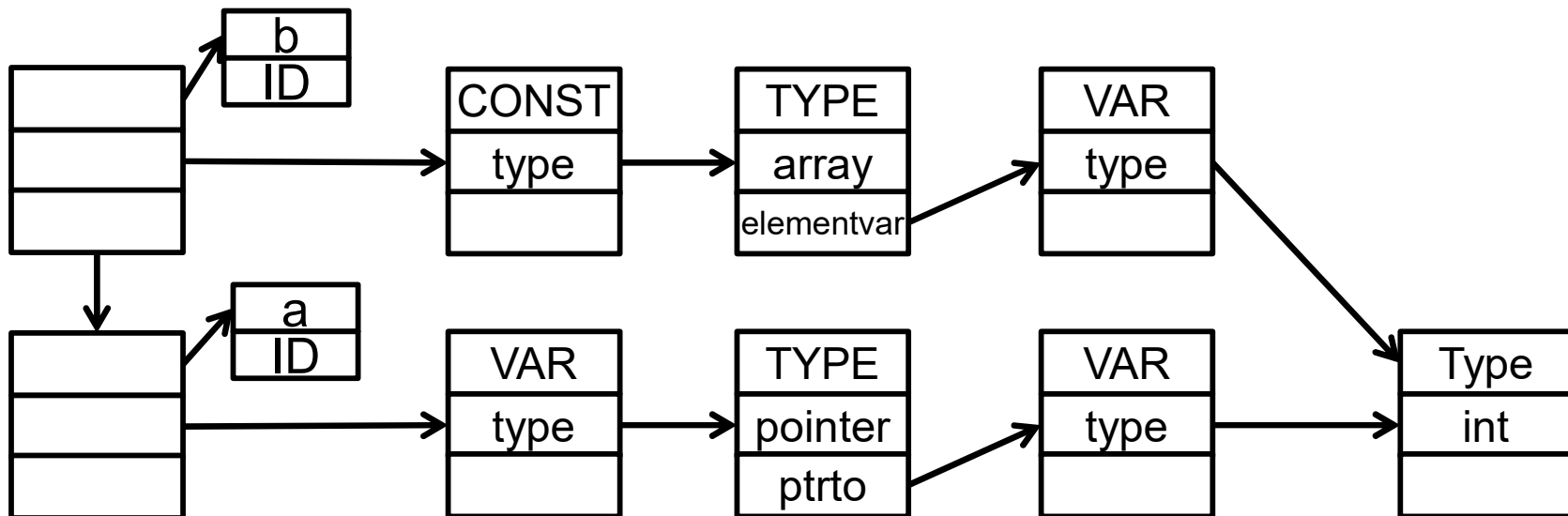
1. LHS가 variable인지 체크
2. RHS가 NULL이고 LHS가 포인터 타입인지 체크
3. LHS와 RHS의 타입이 같은지 체크

```
int a;  
char b;  
a = b; /* error: incompatible types for assignment operation*/  
5 = a; /* error: lvalue is not assignable */  
a = NULL; /* error: cannot assign 'NULL' to non-pointer type */  
a = 5; /* legal */
```

# Type Checking (Assignment Operation)

## Example2

```
int *a;  
int b[10];  
a = b; /* error: incompatible types for assignment */  
b = a; /* error: lvalue is not assignable */
```



# Type Checking (Assignment Operation)

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## Example3

```
int *a[5];
int *b;
int c[10];
struct temp1 { int a; } *s1;
struct temp1 s2;
struct temp2 { int b; } *s3;

a = b; /* error: lvalue is not assignable */
b = c; /* error: incompatible types for assignment operation */
s1 = s3; /* error: incompatible types for assignment operation */
s1 = s2; /* error: incompatible types for assignment operation */
s1 = &s2; /* legal */
```

# Type Checking (Binary +, -)

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## Legal operand

- Only for integer
- $\text{int} \pm \text{int}$

## Error operand

- $\text{Array} \pm \text{int}$
- $\text{int} + \text{Array}$
- $\text{pointer} \pm \text{int}$
- $\text{int} + \text{pointer}$
- ...

# Type Checking (Unary -)

---

Only for integer

```
int a;  
char b;  
  
a = 10;  
b = 'a';  
a = -a;    /* legal */  
b = -b;    /* error */
```

# Type Checking (Logical Operators)

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**&&, ||, !**

**Only for integer**

- `int && int`
- `int || int`
- `! int`

**Input test file**

- int types are derived from Relop, Equop, Logical op
- Don't need to check whether it is derived from relop/equop/logical op or not
  - `ex) a = 5 * (b == 0)      /* OK */`

# Type Checking (INCOP, DECOP)

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**For char, int**

```
int a;  
char b;  
int* c;  
char d[10];  
struct temp { int a;} e;  
  
a++;  
--a;  
b++;  
c++;      /* error */  
--d;      /* error */  
++e;      /* error */
```

# Type Checking (Relop)

---

**>=, >, <=, <**

**char OP char**

**int OP int**

**return int type as a result**

```
int result;  
int a;  
int b;  
result = (a > 5) || ( a <= b );
```



# Type Checking (Equop)

---

**==, !=**

**char OP char**

**int OP int**

**pointer OP pointer (only same type pointer)**

**Return int type as a result**

Pointer == array, array == array 등은 고려하지 않음

```
int result;  
int *a;  
int *b;  
char *c;  
result = ( a == b );  
result = ( a == c ); /* error */
```

# Type Checking (Pointer Operators)

## ➤ Indirection, address-of operator : \*, &

- '\*' must have pointer type operand right
- '&' must have variable type operand right

## ➤ NULL

- You have to implement it properly.
- **0 cannot be used as NULL**

```
int *a;
int b;
int c[10];

a = 0; /* error: incompatible types for assignment */
a = NULL; /* legal */
a = &b; /* legal */
a = *b; /* error: indirection requires pointer operand */
&b = a; /* error: lvalue is not assignable */
b = &c; /* error: cannot take the address of an rvalue */
b = 0; /* legal */
b = *a; /* legal */
```

# Type Checking (Struct Operators)

## ➤ Struct operator : ., ->

- '.' must have structure type operand left.
- '->' must have structure pointer type operand left
- An identifier followed by '.', '->' must be defined as the structure type

```
struct str1 {int i; char c;};

struct str1 st1;
struct str1 *pst1;

int main() {
    int i;
    i = st1.i;
    i = st1.i2; /* error: no such member in struct */
    i = st1->i; /* error: member reference base type is not a struct pointer */
    i = pst1->i;
    i = pst1.i; /* error: member reference base type is not a struct */
}
```

# Type Checking (Array Operator)

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## ➤ Array operator : [ ]

- A[i]
- A must be an array type

```
int a[5];  
int b;  
char c;  
  
b = a[1];  
a[1] = b;  
a[1] = b[1]; /* error: subscripted value is not an array */
```

# Structure & Structure pointer Declaration

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## ➤ Structure

- Structure type must be defined before declaration of the structure type instance
- Structure declaration is **always regarded as a global declaration**
- Redefining structure type is illegal
  - ✓ scope is not applied to struct type
  - ✓ remember this is against C/C++ standard

# Structure & Structure pointer Declaration

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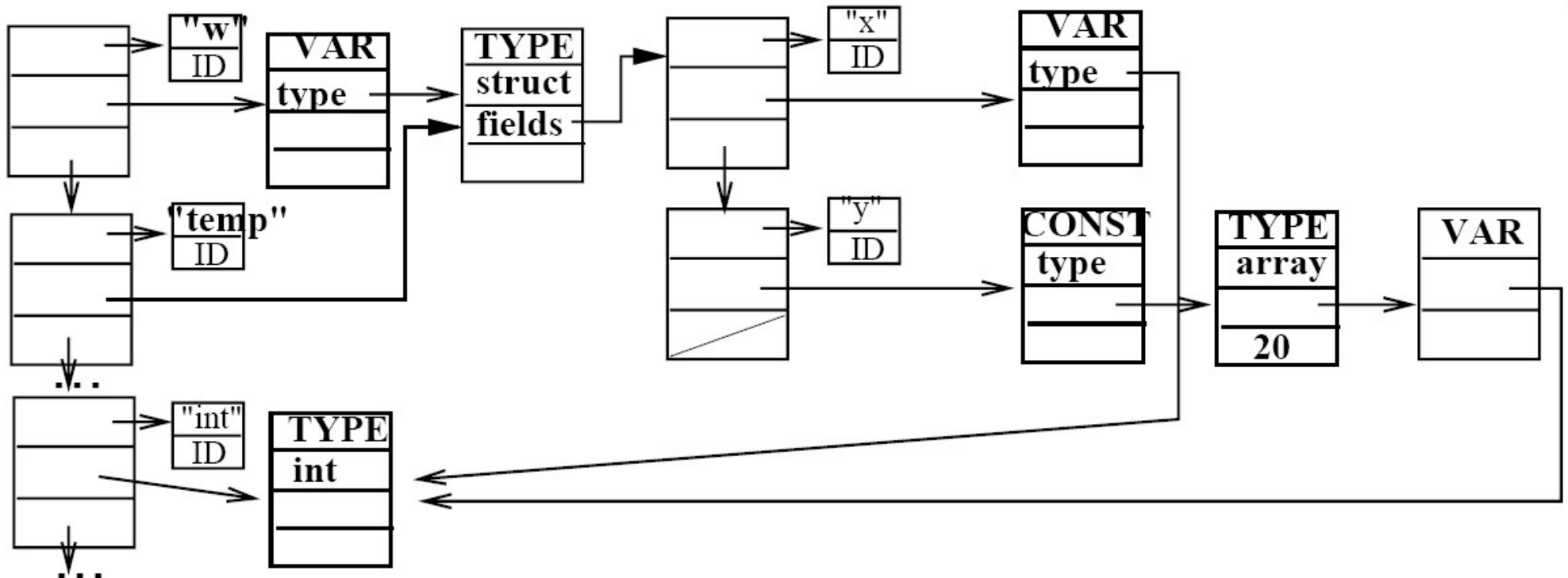
## ➤ Structure Pointer

- When structure pointer type variable is declared, lookup structure type
- Link if the structure type is defined
- Otherwise, generate *incomplete type* error
  - ✓ This is also against ANSI C/C++ standard

# Structure & Structure pointer Declaration

ex)

```
struct temp { int x; int y[20]; } w;  
struct temp *w1;
```



# Structure & Structure pointer Declaration

➤ Struct가 정의되지 않은 상태에서 사용하려 할 때 에러

```
struct a {  
    struct b x;           /* error: incomplete type */  
    struct b* p;          /* error: incomplete type */  
    struct b { } y;       /* OK */  
};  
  
struct b {                /* error: redeclaration */  
};  
  
int func() {  
    struct b { } x;       /* error: redeclaration */  
}
```



# Function Declaration

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- Check return type with the previous function declaration
- Check actual arguments with formal arguments
  - check strictly, not using implicit rules
- Check type of the expression following return type of the function

```
int func1(int a, char b) { return 0; }
int func2(int a, char b) { return 'c'; } /* error:incompatible return types */
int func1() {} /* error: redeclaration */

int main() {
    int a;
    int b;
    char c;
    b = func1(a, b); /* error: incompatible arguments in function call */
    b = func1(a, c);
    c = func1(a, c); /* error: incompatible types for assignment operation */
    b = a(); /* error: not a function */
}
```

```
int foo (int x, int y)
{
    int z, w;
    ...
}
```





# GRAMMAR

# Grammar

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\* **Syntax Error**가 발생하는 코드는 채점 시 테스트 케이스로 들어가지 않음

e.g.

**Cannot declare variable and initialize simultaneously**

➤ `int a = 0; /* syntax error */`

**No anonymous struct declaration**

➤ `struct { int x; int y; } w; /* syntax error */`

**Cannot declare variable after other statement(stmt) in a scope**

➤ `int a;  
int b;  
a = 5; /* stmt */  
int c; /* syntax error */  
{ int a; } /* OK */`

# Grammar

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\* **Syntax Error**는 아니지만 채점 시 테스트 케이스로 들어가지 않는 경우

- 자기 자신을 call하는 함수
- 자기 자신을 멤버로 갖는 구조체
- 리턴문이 없는 함수 (e.g. `int foo() {};` )
- Function overloading
- Assignment of a string constant (e.g. `char* a = "Hello";`)
- 배열과 포인터, 배열과 배열간 비교연산

# Output & Tips

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# Output

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## Output format

- `<filename>:<line_num>:(SPACE)error:(SPACE)<description>`
- Please insert a space right before and after "error:".
- `<filename>` is a second command line argument. (i.e. `argv[1]`)
- Print the error message on the **stdout**.
- Use `get_lineno()` to get a line number. (Project #3 *subc.* skeleton code)
- ex)
  - `test.c:5: error: an error message`

## Helper functions for printing error messages are available in *subc.y*

- Functions starts with "error\_"
  - `error_undeclared()`, `error_redeclaration()`, ...
- Complete the function `error_preamble()` to print line number and file name.

# Skip error code

---

Should be able to **proceed to next step when error occurs**

Return NULL when error occurs

```
int a;
char a;    /* error */
a = 1;     /* legal (int) = (int) */
a = 'c';   /* error */

Var_decl
: pointers ID {
    if($1==0){ // Not pointer
        if(check_is_declared($2))
            declare($2,$$=makevardecl(NULL));
        else
            $$ = NULL;
    }
}
```



# Multiple Errors

여러 에러가 동시에 발생하는 경우, 소스코드의 라인마다 에러는 1개씩만 출력  
(파싱할 때 먼저 찾을 수 있는 에러를 출력)

e.g.

아래 예제의 경우 `expr->unary '=' expr` 를 통한 REDUCE가 일어나기 전  
`unary->unary '[' expr '']` 이 먼저 REDUCE되므로,  
`subscripted value is not an array` 에러만 출력

```
int func() {return 1;}
int main() {
    int a;
    func = a[1]; /* error: lvalue is not assignable,
                  error: subscripted value is not an array */
    return 1;
}
```

# Multiple Errors

한 **Production**에서 여러 에러가 발생해서 **Semantic check**에 우선순위를 정해야 하는 경우가 있다면, 본인이 생각했을 때 더 나은 방향으로 구현한 뒤 보고서에 작성 (채점 시에는 아예 잘못된 에러가 출력되는 경우가 아니라면 맞게 채점할 것)

e.g.

아래 예제의 경우 `expr->unary '=' expr` 에서 REDUCE가 일어날 때,

1) LHS가 variable인 것을 먼저 검사하는지 2) LHS, RHS가 same type 인지를 먼저 검사하는지에 따라 출력되는 메시지가 달라질 것이다.

참고로 이 예제의 경우 9p 에서 따로 순서를 지정해 놓았기에 **lvalue is not assignable** 에러가 출력되는 것이 맞다.

```
int func() {return 1;}
int main() {
    int a;
    func = a;          /* error: lvalue is not assignable
                        error: incompatible types for assignment operation*/
    return 1;
}
```

# Tips

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**Carefully follow the implementation in class handout.**

**Implement your own type check functions for data structures.**

- Improves code readability
- Faster debugging
- Be careful for segmentation fault (accessing NULL pointer)

**Always beware of how information flows while reduce occurs.**

**Check test code in `open_test` directory.**

Ex) `./subc open_test/func_op.c > result`

# Submission

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## 제출 기한

- December 4, 2024

## 제출 방법

- etl.snu.ac.kr을 통해서 제출

## 제출 파일

- 'src' directory 안의 파일들과 'report.pdf' 를 제출
- report.pdf 를 project3 디렉토리 안에 복사한 후 submit.sh 로 압축
  - project3 의 subdirectory 도 인식할 수 있으니 아무 곳에도 넣어도 됨.
  - Project container 안에서 ./submit.sh xxxx-xxxxx 실행
- Archive 의 파일 이름 확인
  - project3\_학번.zip (학번 format은 20xx-xxxxx)

# Teams

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**Project 3 는 최대 2인의 팀을 구성하여 진행 가능**

- 해당 eTL 공지에 댓글로 팀 구성을 명시 (학번 및 이름)
- 제출물 역시 둘 중 한 명만 제출하여도 됨.

**혼자 프로젝트를 완료하면 bonus credit 이 부여됨**

# Notice

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## 수업 게시판 확인

- eTL 공지 및 질문 게시판 항상 확인할 것
- 스펙이 수정 또는 추가되는 사항은 항상 게시판을 통하여 공지
- 제출 마지막날까지 공지된 사항을 반영해서 제출

## 제출 형식 지키기 (파일 이름 및 출력)

- 지키지 않을 시 감점

## Cheating 금지 (F처리, 모든 코드 철저히 검사)

## TA

- 이상현
- E-mail : sanghyeon@snu.ac.kr