

# COMPILERS

## Symbol Tables

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### Semantic Analysis

- The compilation process is driven by the syntactic structure of the program as discovered by the parser.
- Semantic routines:
  - interpret meaning of the program based on its syntactic structure
  - it has two functions:
    - finish analysis by deriving context-sensitive information
    - begin synthesis by generating the IR or target code
- Associated with individual productions of a context free grammar or subtrees of a syntax tree.

## Context Sensitive Analysis - Why

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- What context-sensitive issues can be determined?
  - Is X declared before it is used?
  - Are any names declared but not used?
  - Which declaration of X does this reference?
  - Is an expression type-consistent?
  - Do the dimensions of a reference match the declaration?
  - Where can X be stored? (heap, stack, ...)
  - Does \*p reference the result of a malloc()?
  - Is X defined before it is used?
  - Is an array reference in bounds?
  - Does function foo(...) produce a constant value?

## Context Sensitive Analysis - How

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- How to check symbols and their semantics at various points in the program?
  - Process program linearly (roughly, in-order tree traversal).
  - Maintain a list of currently defined symbols and what they mean as the program is processed – this is called a Symbol Table.

## Symbol Tables

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- Associate lexical names (symbols) with their attributes.
- Can contain:
  - variable names
  - defined constants
  - procedure/function/method names
  - literal constants and strings
  - source text labels
  - compiler-generated temporaries
  - subtables for structure layouts (types) (field offsets and lengths)

## Symbol Table Attributes

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- The following attributes would be kept in a symbol table:
  - textual name
  - data type
  - dimension information (for aggregates)
  - declaring procedure
  - lexical level of declaration
  - storage class (base address)
  - offset in storage
  - if record, pointer to structure table
  - if parameter, by-reference or by-value?
  - can it be aliased? to what other names?
  - number and type of arguments to functions/methods

## Scope

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- ❑ An identifier has scope when it is visible and can be referenced.
- ❑ An out-of-scope identifier cannot be referenced.
- ❑ Identifiers in open scopes may override older/outer scopes temporarily.
- ❑ 2 Types of scope:
  - Static scope is when visibility is due to the lexical nesting of subprograms/blocks.
  - Dynamic scope is when visibility is due to the call sequence of subprograms.

## Why Scope?

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- ❑ Scope is not necessary.
  - Languages such as assembler have exactly one scope: the whole program.
- ❑ Modern programming languages have more than one scope.
  - Information hiding and modularity.
- ❑ Goal of any language is to make the programmer's job simpler.
  - One way: keep things isolated.
  - Make each thing only affect a limited area.
  - Make it hard to break something far away.

## Scope in a symbol table

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- Most modern programming languages have nested static scope.
  - The symbol table must reflect this.
- What additional information can reflect nested scope?
  - A name query must access the most recent declaration, from the current scope or some enclosing scope.
  - Innermost scope overrides declarations from outer scopes.

## Symbol Table Implementation

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- Implemented as a collection of dictionaries in which each symbol is placed.
- Two operations:
  - insert adds a binding to a table and
  - lookup locates the binding for a name.
- Many different possible data structures:
  - linked list
  - hash table
  - binary tree

## Symbol Table Lookup

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- ❑ Basic operation is to find the entry for a given symbol.
- ❑ Each symbol table may have a pointer to its parent scope.
- ❑ Lookup: if symbol in current table, return it, otherwise look in parent.
- ❑ Hash tables and binary trees can be used more efficiently.

## Symbols vs. Names

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- ❑ Names are the textual entities found in the source code.
- ❑ Symbols are entities assigned to each name for more efficient processing during compilation.
- ❑ Example:
  - Name: valueA
    - ❑ Symbol: V001
  - Name: valueB
    - ❑ Symbol: V002
- ❑ Remember perfect hash functions?

## Type Checking

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- Static semantics should be checked after/as the symbol table is populated.
  - Is every name defined before it is used?
  - Does the type of each subexpression conform to what is expected?
  - Are the types on either side of an assignment compatible?
- The tree can be walked/visited to perform these checks.
  - May need multiple passes – so retain symbol table across passes.

## Type Equivalence

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- Two approaches:
  - Name equivalence: each type name is a distinct type.
  - Structural equivalence: two types are equivalent iff. they have the same structure (after substituting type expressions for type names).
- Example (structural):

```
typedef int bignumber;  
int c;  
bignumber b =c;
```

## Error Handling

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- ❑ If errors are detected, correct program representation and continue analysis to detect other errors.

- ❑ Example:

```
int a, b;  
String c;  
c = a;  
b = a;
```