

Naming, Scoping, and Binding

LR Parsers

- SLR(1) – LR(0) items (construct DFA for recognizing viable prefix with no lookahead), use FOLLOW information to guide reductions
- LALR(1) – merge states of LR(1) with same core (LR(0) items)
- LR(1) – store lookahead information in DFA
- LR(k)

More
general
↓

Types of Conflicts

- Ambiguous grammar constructs resulting in multiple actions in action table
 - Shift/reduce ($S \leftarrow Ay, A \leftarrow x|xy$) – can opt in favor of longest match, i.e., shift, or modify grammar to eliminate it – classic example is dangling else
 - Reduce/reduce – ($S \leftarrow Ax|Bxy, A \leftarrow x, B \leftarrow x$) – often no simple solution

Parsing Review

	Advantages	Disadvantages
Recursive descent or predictive LL(1)	Fast Simple Automatable	No left recursion $LL(1) \subset LR(1)$
LR(1)	Fast Automatable	Larger table size Right recursion can be inefficient

- Name – a character string or identifier used to represent something
 - Provide a level of abstraction – control (e.g., subroutine) or data (classes)
- Binding – an association between a name and the thing it names
- Scope – textual region in the program in which a binding is active
 - The set of active bindings is called the current referencing environment

Binding Time

- The time at which a binding is created (time at which implementation decision is made)
 - Language design time
 - Language implementation time
 - Program writing time
 - Compile time
 - Link time
 - Load time
 - Run time
- Static binding – before run time
Dynamic binding – at run time

Object Lifetime and Storage Management

- Events
 - Creation of objects
 - Creation of bindings
 - References to variables, subroutines, types, etc., all of which use bindings
 - Deactivation and reactivation of bindings
 - Destruction of bindings
 - Destruction of objects

Binding's lifetime –

Period of time between creating and destruction of name-to-object binding

Storage Allocation Mechanisms

- Static objects – given an absolute address since they are retained throughout the program
- Stack objects – allocated in LIFO order, usually in conjunction with subroutine calls and returns
- Heap objects – allocated and deallocated at arbitrary times – more general and expensive storage management

Scope Rules

- Scope
 - a program region of maximal size in which no bindings change
 - name space that maps a set of names to a set of variables
- Scope of a binding
 - Static – can be determined based purely on textual rules at compile time
 - Dynamic – depends on the flow of execution at run time
- Lifetime of a variable – single execution of the scope or multiple executions of the scope (decides where data can be allocated)

Static Scope

- Only a single global scope, variables declared by virtue of being used - Basic
- Global and local scope – e.g., C, Fortran (variable declaration optional (assumed to be local), "common blocks" used to "import" global variables into subroutines)
- Closest lexically nested scope rule (nested subroutines) – e.g., Pascal (Algol family)
- Modules (collection of objects - subroutines, variables, types, etc.) with internals/externals invisible unless explicitly exported/imported – inactive bindings outside (not destroyed) – e.g., separate compilation facilities of C, namespaces in C++
 - Closed scope – requiring explicit import (Modula)
 - Open scope – one not requiring explicit import (Ada, nested subroutines)
 - All scopes surrounding the current scope
- Module types and classes – multiple instances, requiring creation/initialization and destruction, specification of instance – Simula, Euclid
 - Class – object-oriented programming construct, includes inheritance, e.g., Smalltalk, Eiffel, C++, Java

Dynamic Scope

- Depends on the order in which subroutines are called – current binding is the most recent encountered during execution – e.g., Perl, APL, Snobol

Shallow vs. Deep Binding

- References to subroutines (e.g., passed as parameter) can have scope rules applied
 - When reference is first created (deep)
 - When routine is finally called (shallow)

Overloading

- Name that can refer to more than one object in a given scope is said to be overloaded, e.g., addition operator (+) used for integer and floating point addition
- Lookup routine of symbol table must return list of possible meanings for the requested name
- Semantic analyzer makes choice based on context (number and types of arguments, for example)
- Distinguish between overloading, coercion, polymorphism, generics
 - Coercion – automatic conversion by compiler from one type to another
 - Polymorphic parameters – represent unconverted arguments of several types with common characteristics (e.g., counting elements in a linked list) – single object capable of accepting multiple types
 - Generic subroutines – template that can be used to create multiple concrete subroutines that differ in minor ways – multiple objects that accept arguments of different types

Aliasing

- More than one name for the same thing – save space
 - Fortran – use common blocks in different ways (equivalence statement) – improve code efficiency
 - C unions – multiple representations

Modules

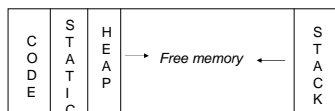
- Collection of subroutines, variables, types, etc. that are visible to each other but invisible outside unless explicitly exported
 - Clu, Modula, Turing, Ada
 - Separate compilation in C
 - Import data/functions using "extern"
 - "static" outside a function means it is usable only inside the current source file
- Closed (Modula) versus open (Ada) scopes
- Modules as types to allow multiple instances – Simula, Euclid
- Classes – module types augmented with inheritance – Smalltalk, Eiffel, C++, Java

Procedures

- Control abstraction
 - Well-defined entry/exits
 - Mechanism to pass parameters, return values
- Name space/scope
 - New name space within procedure
 - Local names are protected from outside
- External interface
 - Accessed by procedure name, parameters
 - Protection for both caller and callee
 - Enables software libraries, systems
- Separate compilation
 - Compile procedures independently
 - Keeps compile times reasonable
 - Allows us to build large programs

Run-Time Storage Organization

Typical memory layout



→ Allows both stack and heap maximal freedom

Scoping Rules of Languages

- LISP
 - Dynamic scoping
 - Most recently invoked procedure
- Algol, Pascal, Modula
 - Nested lexical scoping
 - Procedures nested within procedures
- Fortran 77
 - Global scope – common blocks
 - Local scope – variables, parameters in procedures

Scoping Rules of Languages

- C
 - Global scope – procedures, external variables
 - File scope – variables declared in files
 - Procedure scope – local variables
 - Nested block scope – within {}
- Java
 - Global scope – public classes
 - Package scope – fields, methods within package
 - Procedure scope – local variables
 - Nested block scope – within {}

Symbol Table (for static scoping)

- Maps names to the information the compiler knows about them
- Basic operations – insert, lookup
- Each scope assigned a serial number
 - Predefined identifiers assigned 0
 - Global scope assigned 1
 - Additional scopes given successive numbers as they are encountered
- All names regardless of scope entered in a single large hash table, keyed by name
 - Entry contains symbol name, category, scope number, type, etc.
- Scope stack to maintain current referencing environment
 - Used by semantic analyzer

Association Lists and Central Reference Tables (Dynamic Scope)

- Association list – list of name/value pairs (e.g., Lisp)
 - Functions as a stack
 - Search from front of list until appropriate binding is found (inefficient)
- Central reference table – list (stack) of entries for each distinct name in the program, most recent occurrence at top
 - Lookup operations faster

Scanning Complexities of Real Programming Languages

- Fortran 66 and 77 – blanks not significant
 - PL/I – no reserved keywords
 - C++ - template definition
 - `PriorityQueue<MyType<int>>`
 - `>>` is a C++ operator – distinction requires coordination between scanner and parser
- Sound theoretical basis for scanning probably influenced language design in a positive way!

Parsing Complexities in Real Languages

- Using one word to represent two different meanings – ambiguous grammar
 - E.g., function and array reference in Fortran
- Left versus right recursion
 - Top-down parsers need right recursive grammars
 - Bottom-up parsers can accommodate both, however, right recursive grammar requires more stack space
- Associativity –
 - Left recursion naturally produces left associativity
 - Right recursion naturally produces right associativity

Naming Complexities in Language Design

- Recursive subroutine cannot declare a local object with the same name as the subroutine itself – problem in Pascal that returns values by assigning to function name
- External declarations in C