Semantic actions for expressions

Semantic actions

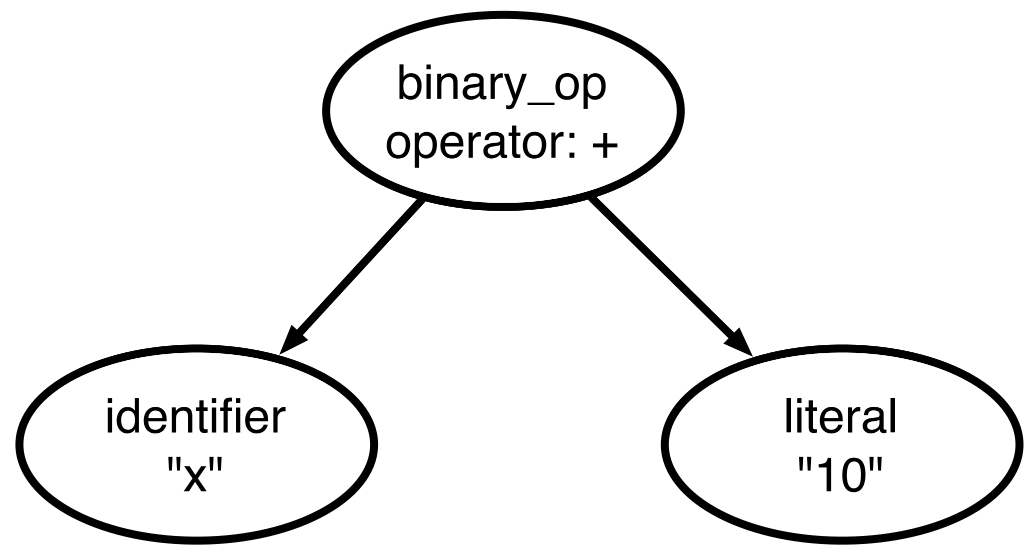
- *Semantic actions* are routines called as productions (or parts of productions) are recognized
- Actions work together to build up intermediate representations
- Conceptually think of this as follows:
  - Every non-terminal should have some information associated with it (code, declared variables, etc.)
  - Each child of a non-terminal can pass the information it has to its parent non-terminal, which uses the information from its children to build up more information
  - We call these *semantic records*

Semantic Records

- Data structures produced by semantic actions
- Associated with both non-terminals (code structures) and terminals (tokens/symbols)
- Build up semantic records by performing a bottom-up walk of the parse tree (as described in class)

Abstract syntax trees

- Tree representing structure of the program
  - Built by semantic actions
  - Some compilers skip this
- AST nodes
  - Represent program construct
  - Store important information about construct



Referencing identifiers

- What do we return when we see an identifier?
  - Check if it is symbol table
  - Create new AST node with pointer to symbol table entry
  - Note: may want to directly store type information in AST (or could look up in symbol table each time)

Referencing Literals

- What about if we see a literal?

  primary → INTLITERAL | FLOATLITERAL

- Create AST node for literal
- Store string representation of literal
  - "155", "2.45" etc.
- At some point, this will be converted into actual representation of literal
  - For integers, may want to convert early (to do *constant folding*)
  - For floats, may want to wait (for compilation to different machines). Why?

Expressions

- Three semantic actions needed
  - eval_binary (processes binary expressions)
    - Create AST node with two children, point to AST nodes created for left and right sides
  - eval_unary (processes unary expressions)
    - Create AST node with one child
  - process_op (determines type of operation)
    - Store operator in AST node

Expressions example

- $x + y + 5$

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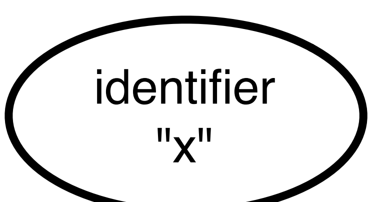

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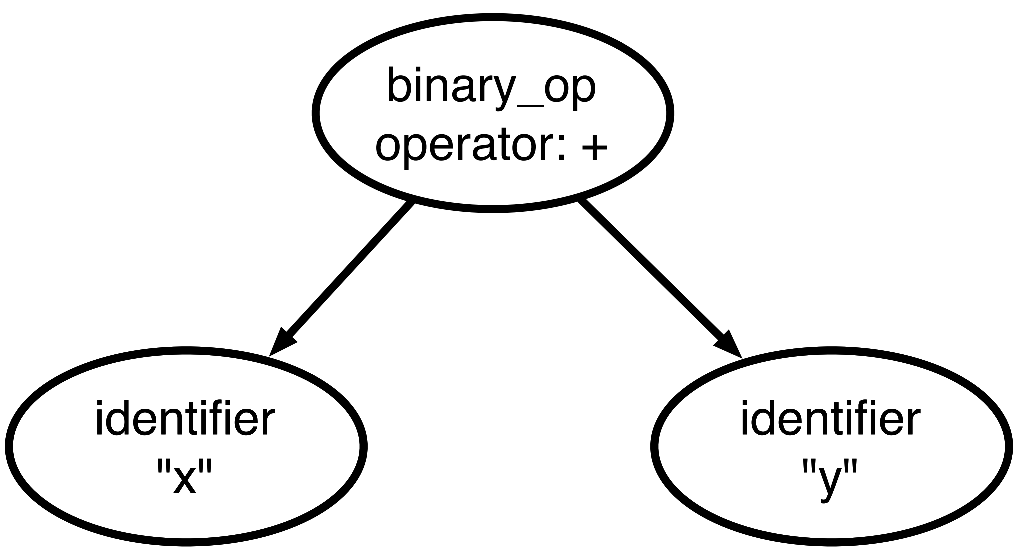

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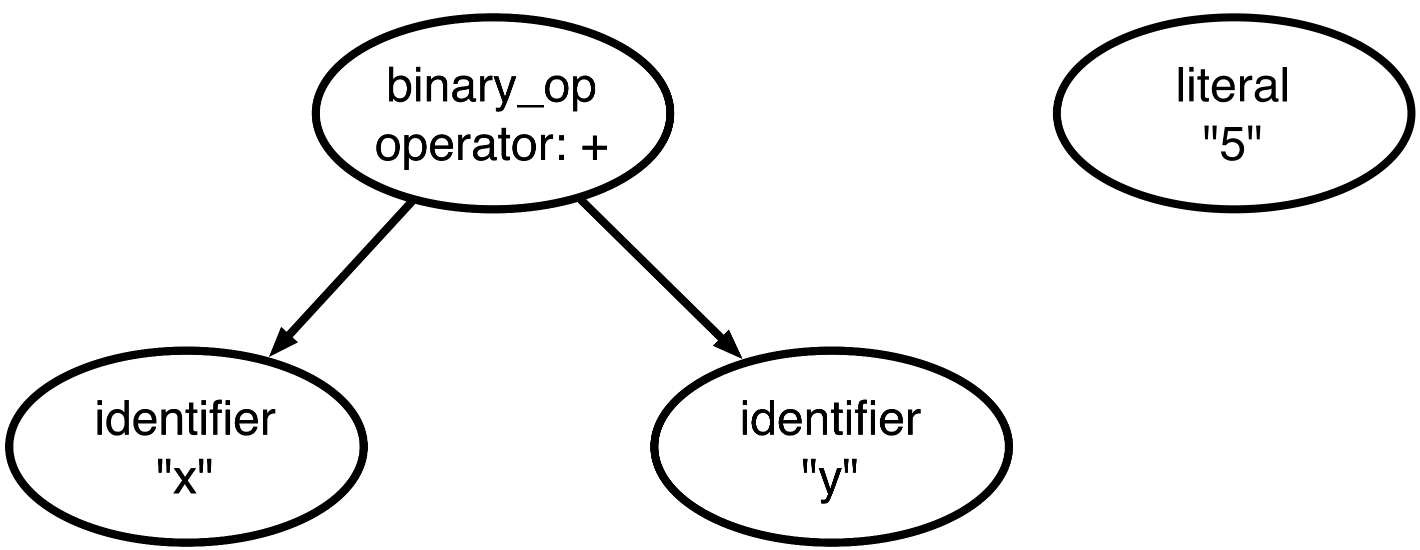

Expressions example

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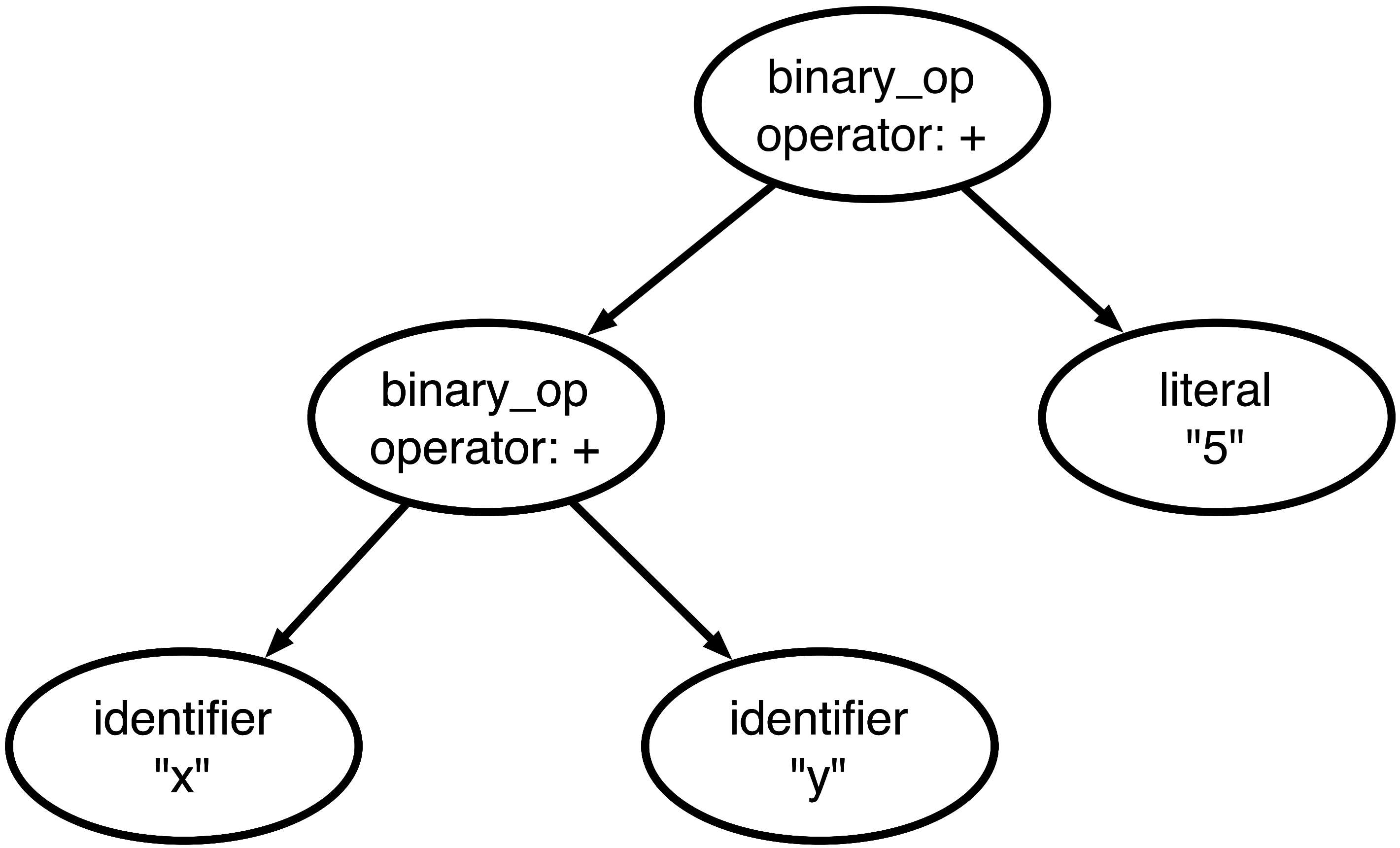

Generating three-address code

- For project, will need to generate three-address code
  - op A, B, C //C = A op B
- Can do this directly or after building AST

Generating code from an AST

- Do a post-order walk of AST to generate code, pass generated code up

```
data_object generate_code() {
  //pre-processing code
  data_object lcode = left.generate_code();
  data_object rcode = right.generate_code();
  return generate_self(lcode, rcode);
}
```

- Important things to note:
  - A node generates code for its children before generating code for itself
  - Data object can contain code or other information

Generating code directly

- Generating code directly using semantic routines is very similar to generating code from the AST
  - Why?
  - Because post-order traversal is essentially what happens when you evaluate semantic actions as you pop them off stack
  - AST nodes are just semantic records
- To generate code directly, your semantic records should contain structures to hold the code as it's being built

Data objects

- Records various important info
  - The temporary storing the result of the current expression
  - Flags describing value in temporary
    - Constant, L-value, R-value
  - Code for expression

L-values vs. R-values

- L-values: addresses which can be stored to or loaded from
- R-values: data (often loaded from addresses)
  - Expressions operate on R-values
- Assignment statements:

  `L-value := R-value`

- Consider the statement `a := a`
  - the `a` on LHS refers to the memory location referred to by `a` and we store to that location
  - the `a` on RHS refers to data *stored in* memory location referred to by `a` so we will load from that location to produce the R-value

Temporaries

- Can be thought of as an unlimited pool of registers (with memory to be allocated at a later time)
- Need to declare them like variables
- Name should be something that cannot appear in the program (*e.g.*, use illegal character as prefix)
- Memory must be allocated if address of temporary can be taken (e.g. $a := \&b$)
- Temporaries can hold either L-values or R-values

Simple cases

- Generating code for constants/literals
    - Store constant in temporary
    - Optional: pass up flag specifying this is a constant
- Generating code for identifiers
    - Generated code depends on whether identifier is used as L-value or R-value
        - Is this an address? Or data?
    - One solution: just pass identifier up to next level
        - Mark it as an L-value (it's not yet data!)
        - Generate code once we see how variable is used

Generating code for expressions

- Create a new temporary for result of expression
- Examine data-objects from subtrees
- If temporaries are L-values, load data from them into new temporaries
    - Generate code to perform operation
    - In project, no need to explicitly load (variables can be operands)
- If temporaries are constant, can perform operation immediately
    - No need to perform code generation!
- Store result in new temporary
    - Is this an L-value or an R-value?
- Return code for entire expression

Generating code for assignment

- Store value of temporary from RHS into address specified by temporary from LHS
  - Why does this work?
  - Because temporary for LHS holds an address
    - If LHS is an identifier, we just stored the address of it in temporary
    - If LHS is complex expression

      ```
      int *p = &x
      *(p + 1) = 7;
      ```

      it *still* holds an address, even though the address was computed by an expression

Pointer operations

- So what do pointer operations do?
- Mess with L and R values
- & (address of operator): take L-value, and treat it as an R-value (without loading from it)

  ```
  x = &a + 1;
  ```

- * (dereference operator): take R-value, and treat it as an L-value (an address)

  ```
  *x = 7;
  ```