

# MIT 6.035

# Semantic Analysis

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# Error Issue

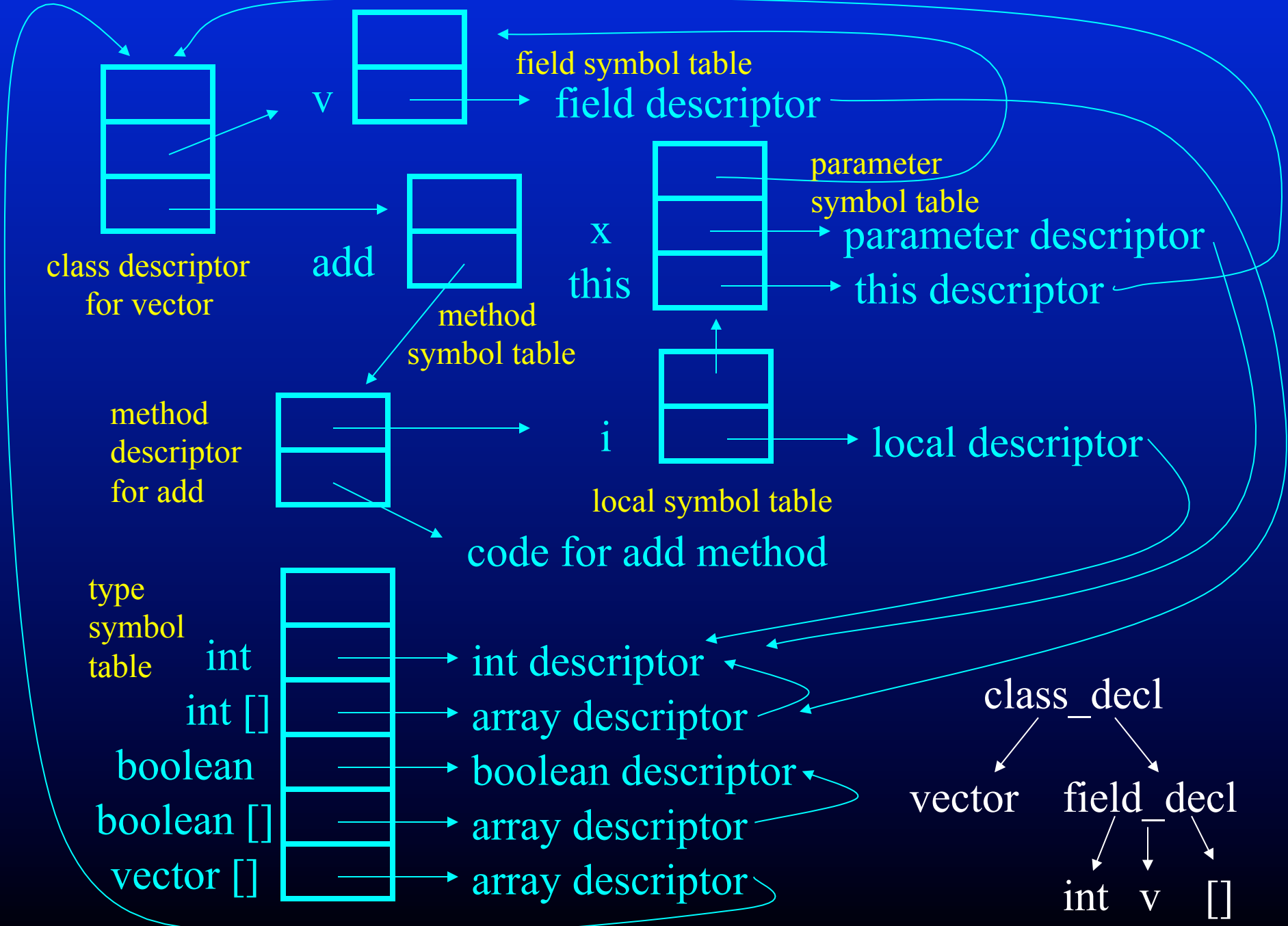
- Have assumed no problems in building IR
- But are many static checks that need to be done as part of translation
- Called Semantic Analysis

# Goal of Semantic Analysis

- Ensure that program obeys certain kinds of sanity checks
  - all used variables are defined
  - types are used correctly
  - method calls have correct number and types of parameters and return value
- Checked when build IR
- Driven by symbol tables

# Symbol Table Summary

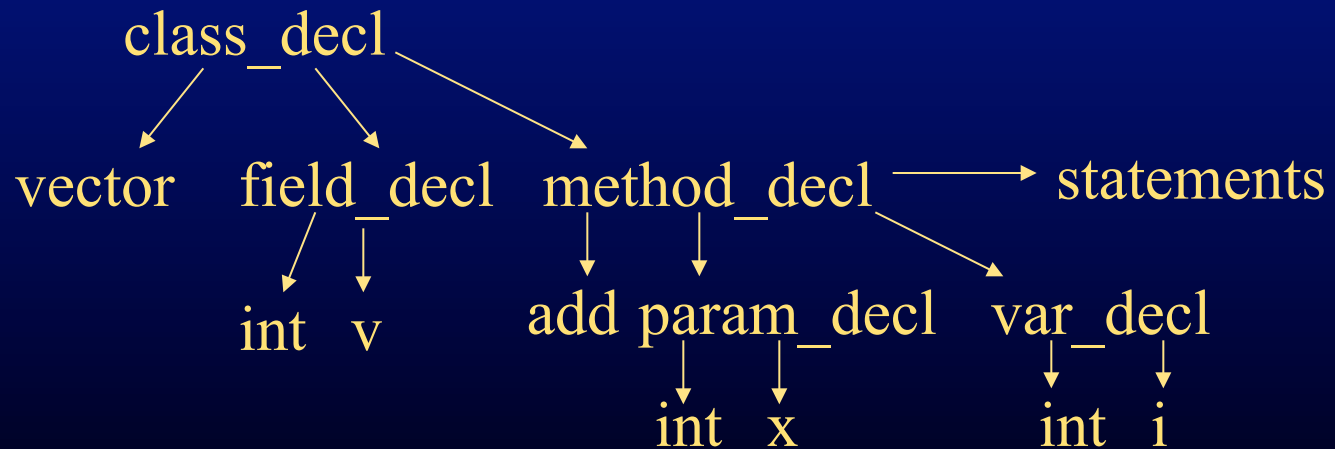
- Program Symbol Table (Class Descriptors)
- Class Descriptors
  - Field Symbol Table (Field Descriptors)
    - Field Symbol Table for SuperClass
  - Method Symbol Table (Method Descriptors)
    - Method Symbol Table for Superclass
- Method Descriptors
  - Local Variable Symbol Table (Local Variable Descriptors)
    - Parameter Symbol Table (Parameter Descriptors)
      - Field Symbol Table of Receiver Class
- Local, Parameter and Field Descriptors
  - Type Descriptors in Type Symbol Table or Class Descriptors

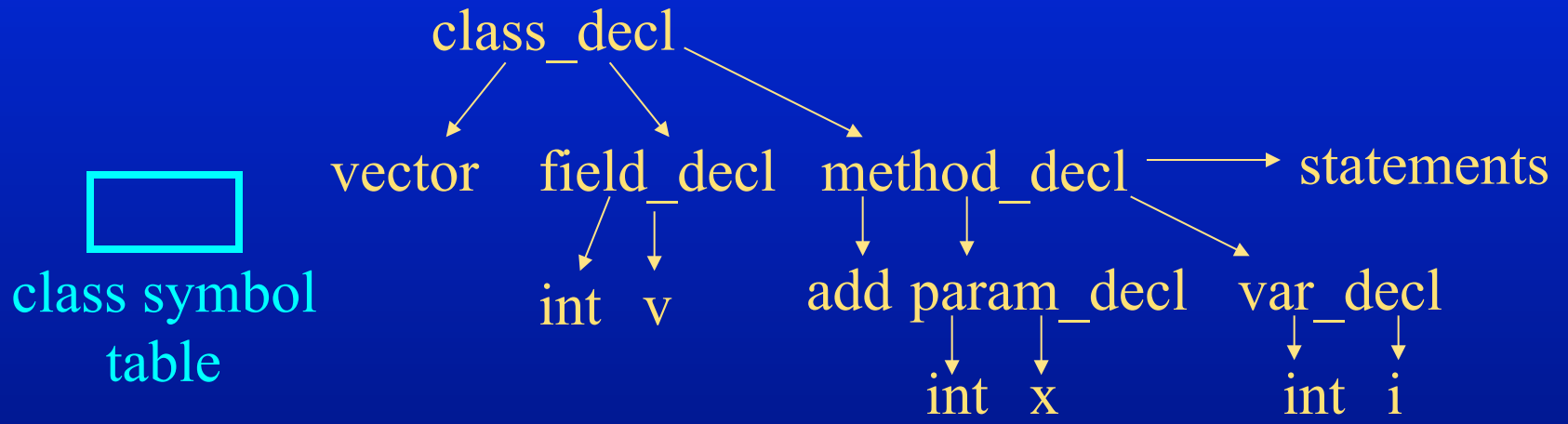


# Translating from Abstract Syntax Trees to Symbol Tables

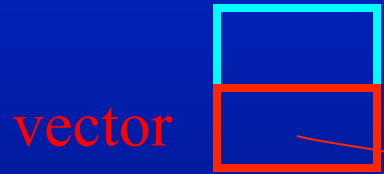
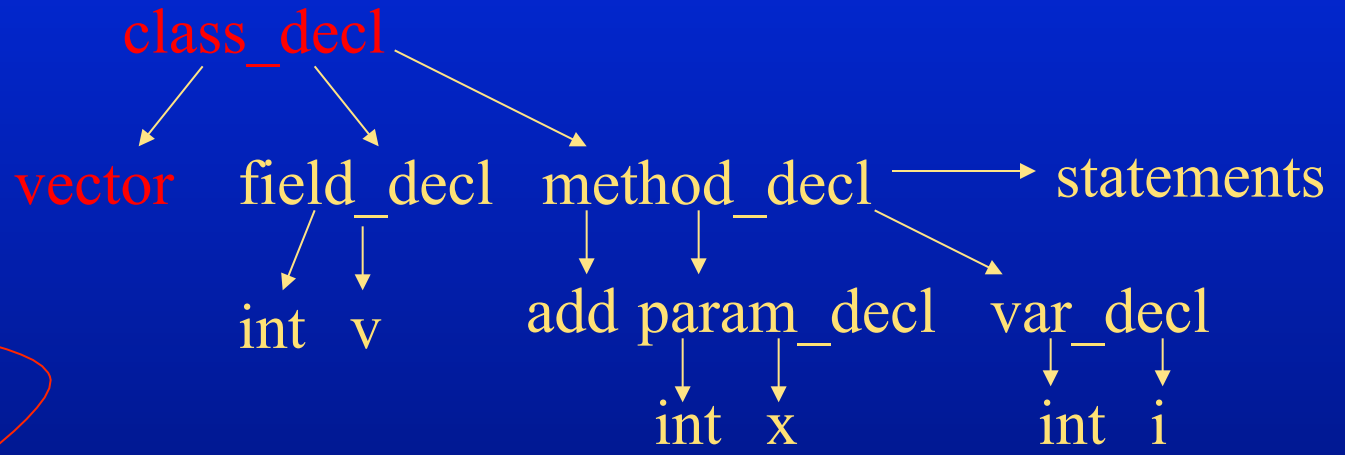
# Intermediate Representation for Classes

```
class vector {  
    int v[];  
    void add(int x) {  
        int i; i = 0;  
        while (i < v.length) { v[i] = v[i]+x; i = i+1; }  
    }  
}
```

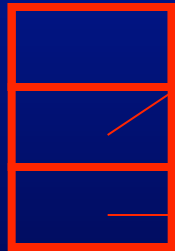




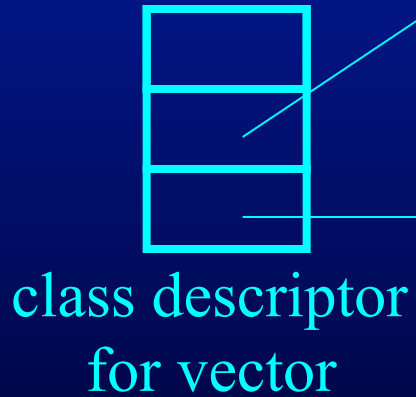
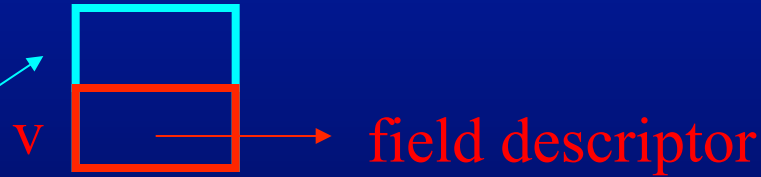
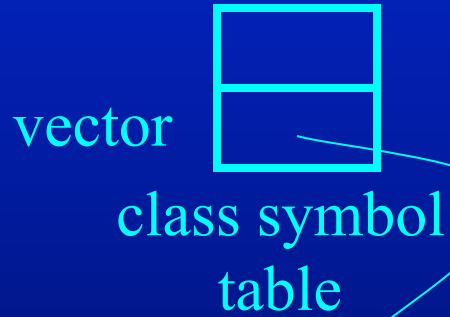
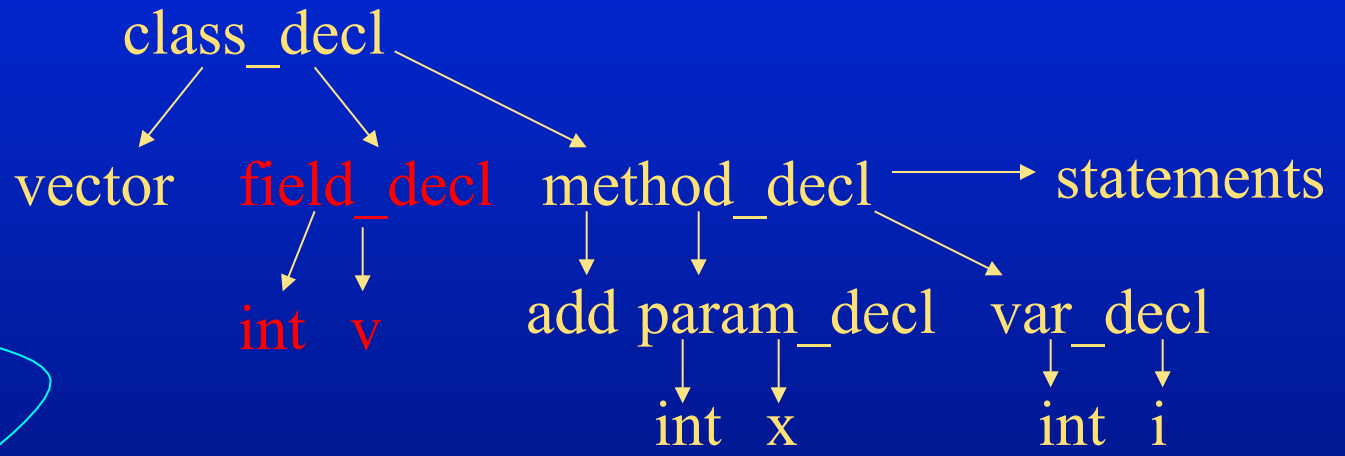


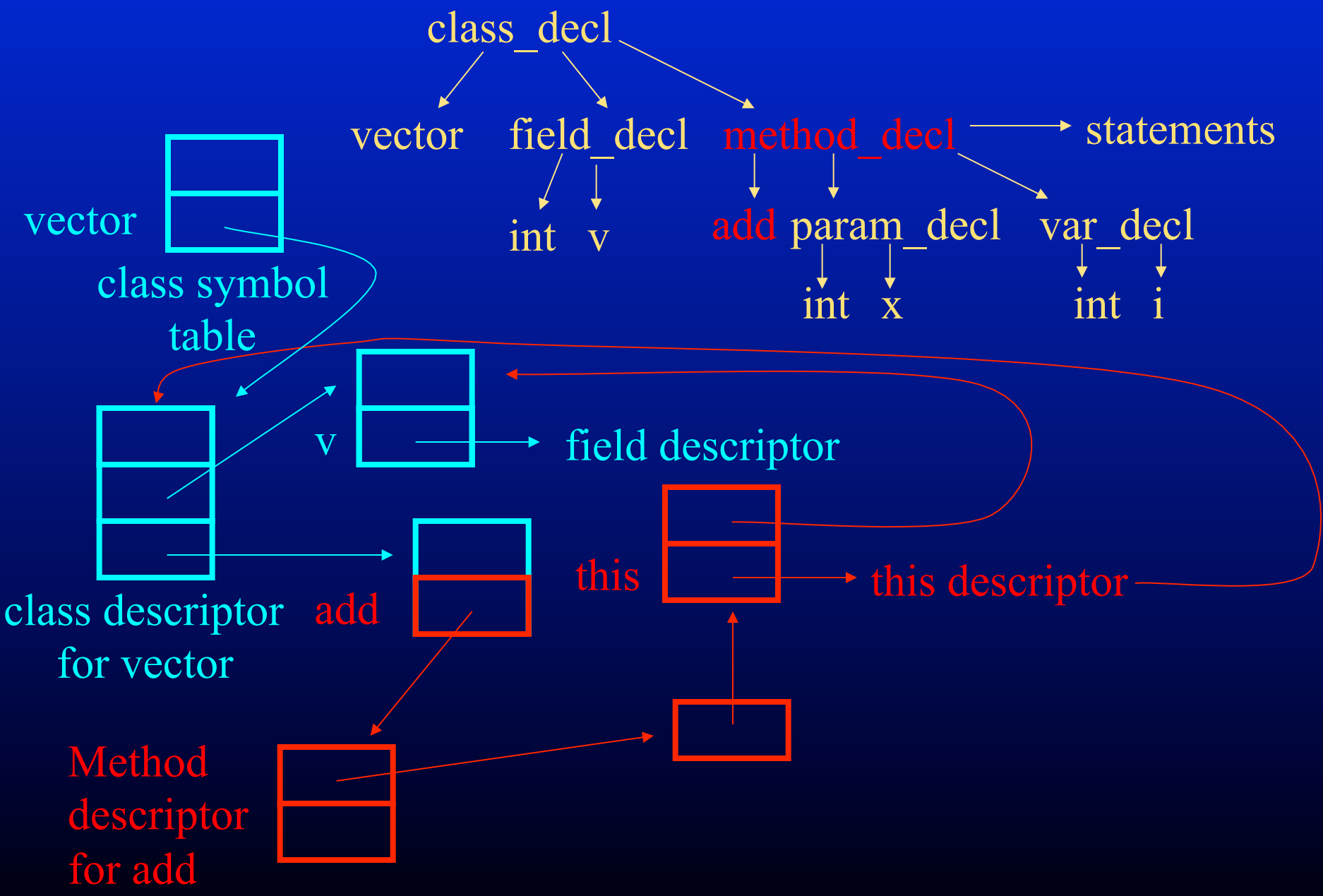


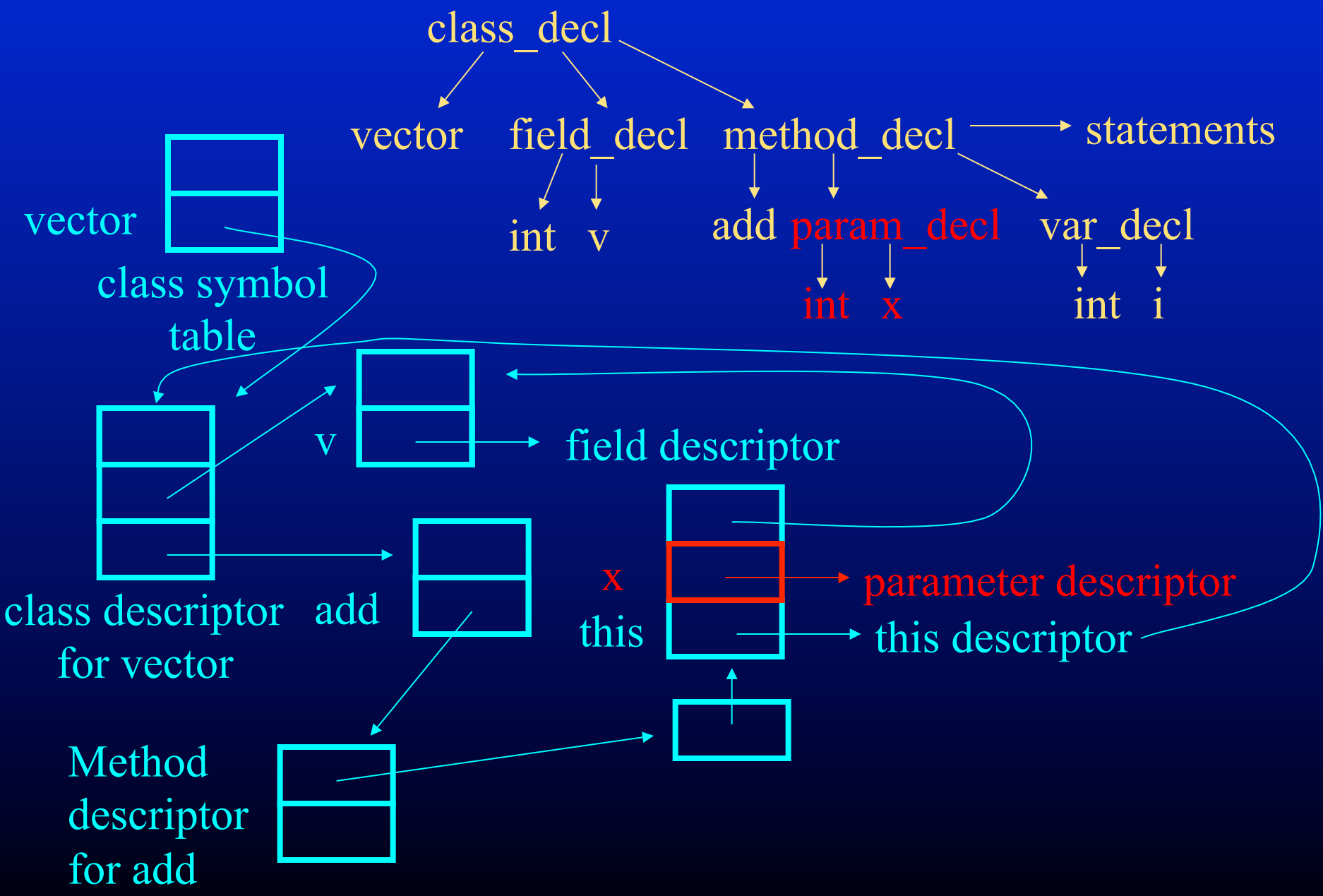
class symbol  
table

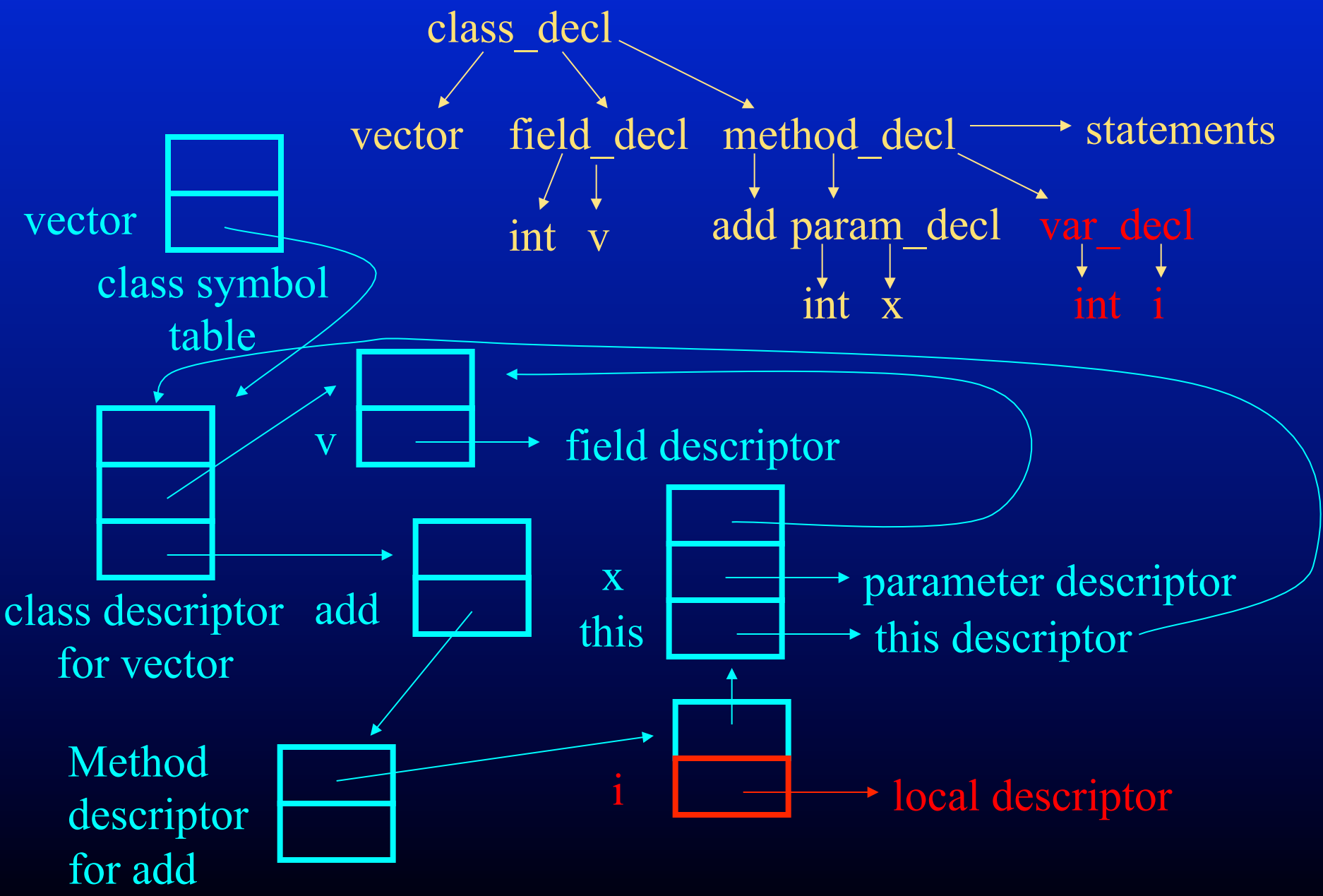


class descriptor  
for vector





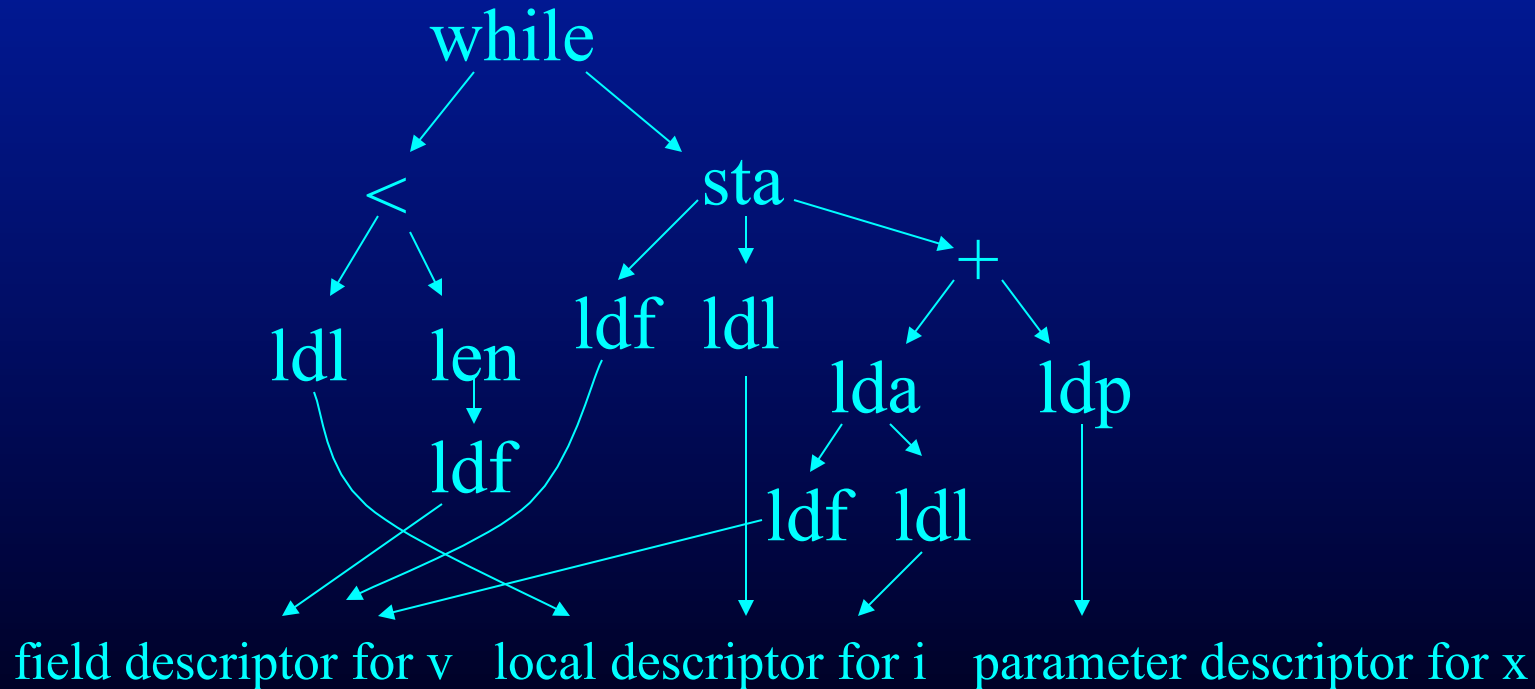




# Intermediate Representation for Code

while (i < v.length)

v[i] = v[i]+x;

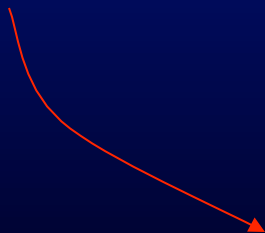


```
while (i < v.length)
    v[i] = v[i]+x;
```

field descriptor for v   local descriptor for i   parameter descriptor for x

```
while (i < v.length)
    v[i] = v[i]+x;
```

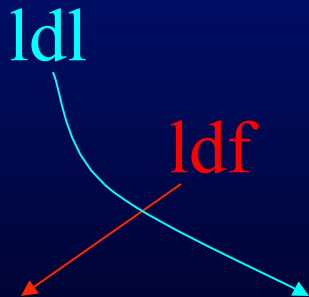
ldl



field descriptor for v   local descriptor for i   parameter descriptor for x

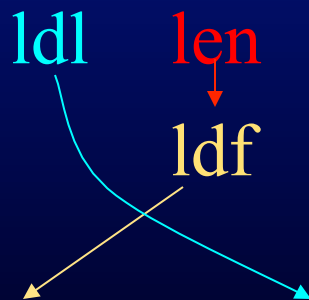


```
while (i < v.length)
    v[i] = v[i]+x;
```



field descriptor for v   local descriptor for i   parameter descriptor for x

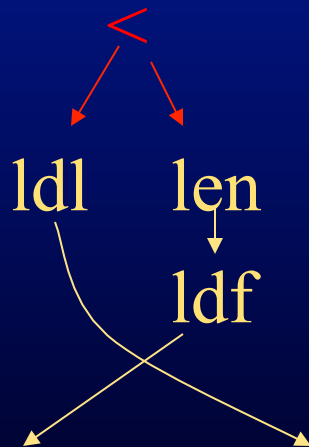
```
while (i < v.length)
    v[i] = v[i]+x;
```



field descriptor for v   local descriptor for i   parameter descriptor for x

```
while (i < v.length)
```

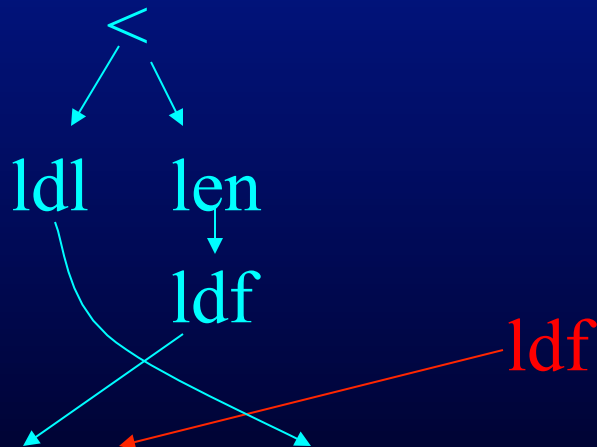
```
    v[i] = v[i]+x;
```



field descriptor for v   local descriptor for i   parameter descriptor for x

while (i < v.length)

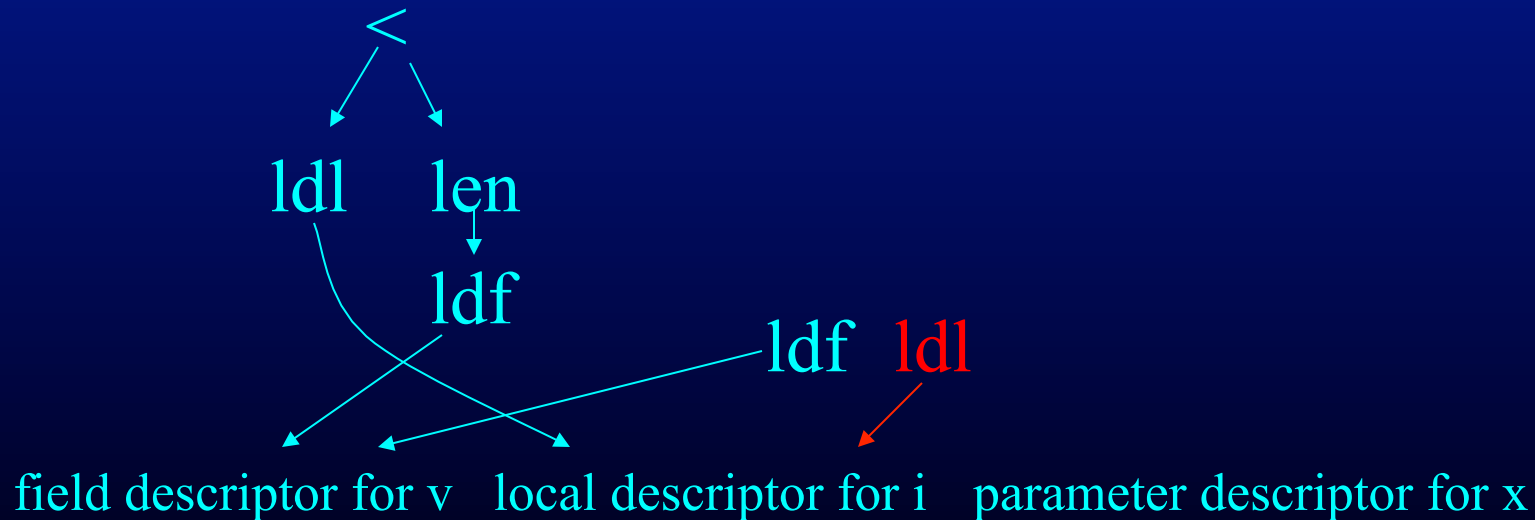
v[i] = v[i]+x;



field descriptor for v   local descriptor for i   parameter descriptor for x

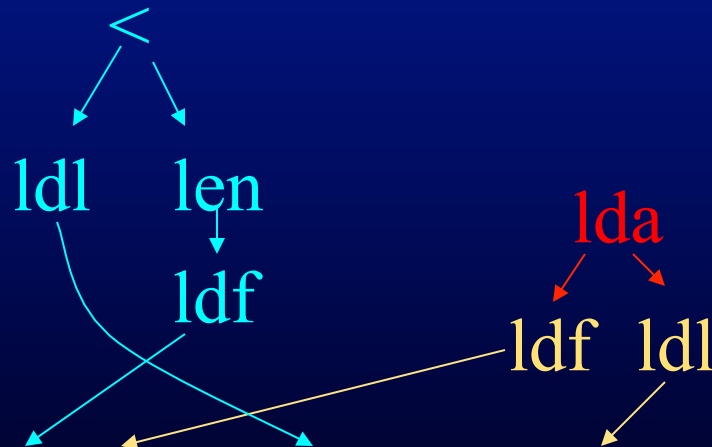
while (i < v.length)

v[i] = v[i]+x;



while (i < v.length)

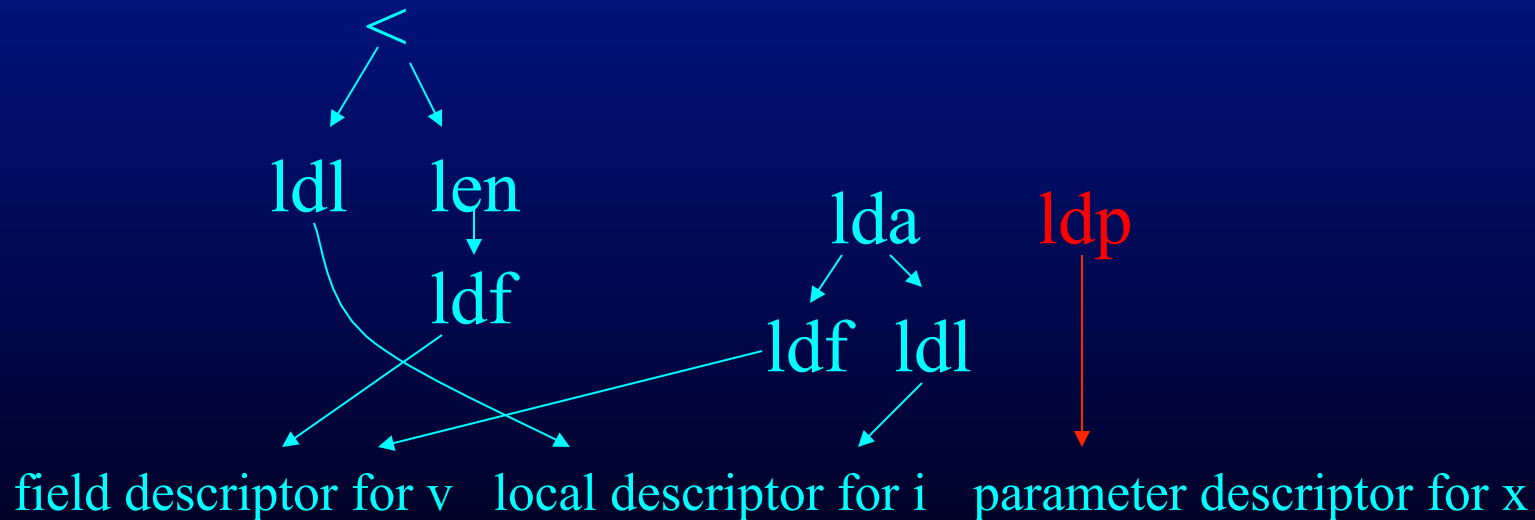
v[i] = v[i] + x;



field descriptor for v    local descriptor for i    parameter descriptor for x

while (i < v.length)

v[i] = v[i] + x;



```
while (i < v.length)
```

```
v[i] = v[i] + x;
```

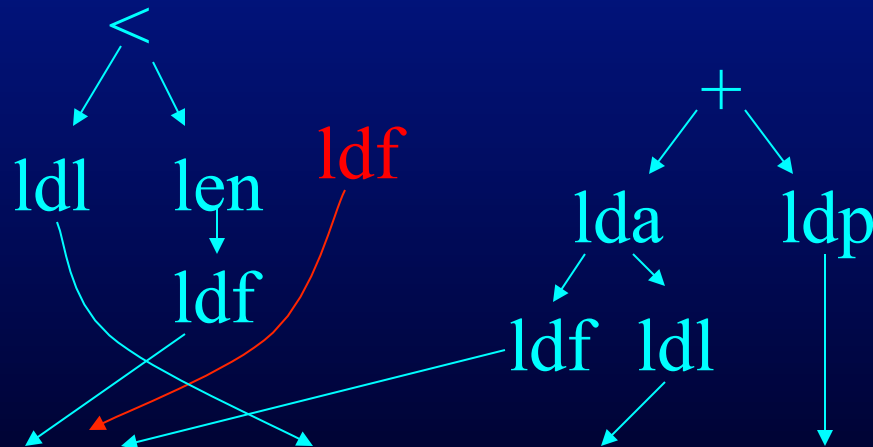


field descriptor for v    local descriptor for i    parameter descriptor for x



while (i < v.length)

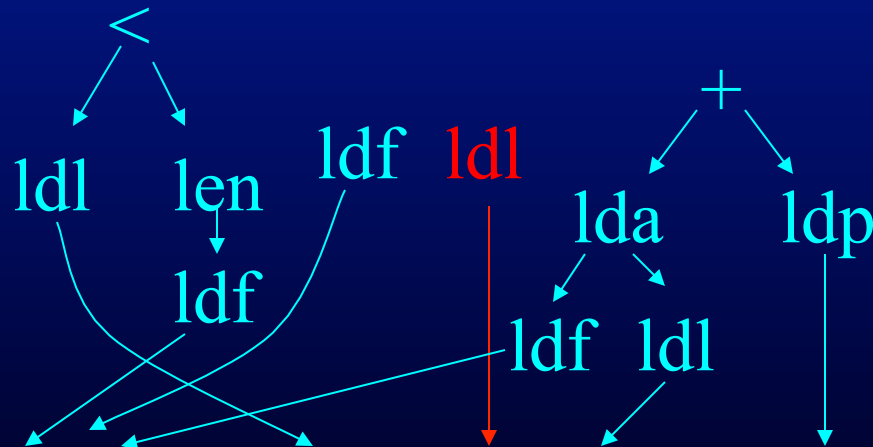
**v**[i] = v[i]+x;



field descriptor for v   local descriptor for i   parameter descriptor for x

while ( $i < v.length$ )

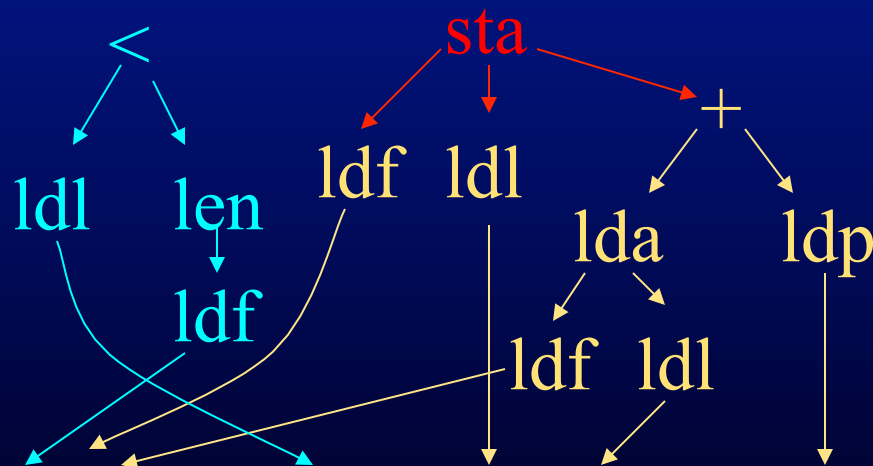
$v[i] = v[i] + x;$



field descriptor for v    local descriptor for i    parameter descriptor for x

```
while (i < v.length)
```

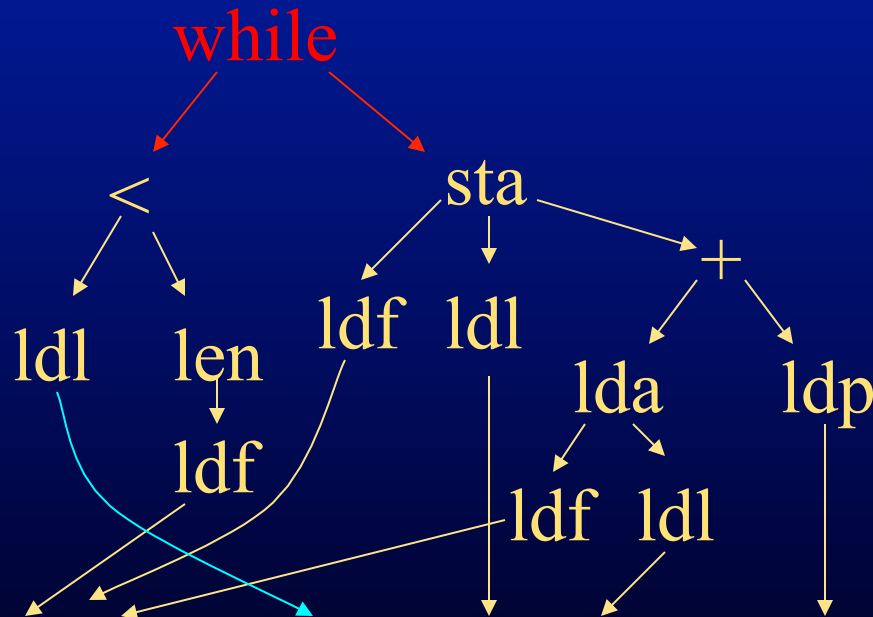
$v[i] = v[i] + x;$



field descriptor for v    local descriptor for i    parameter descriptor for x

**while** (i < v.length)

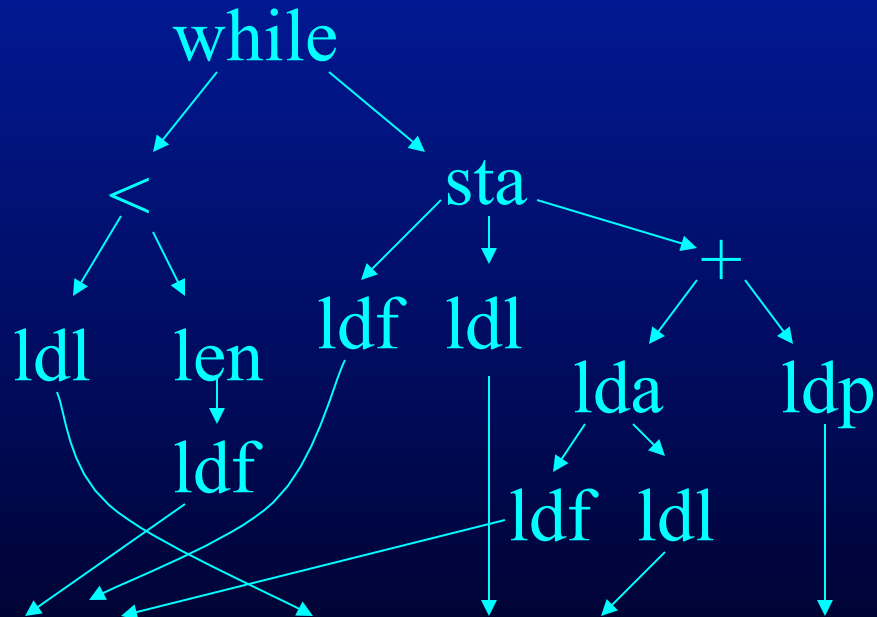
v[i] = v[i]+x;



field descriptor for v   local descriptor for i   parameter descriptor for x

while (i < v.length)

v[i] = v[i]+x;

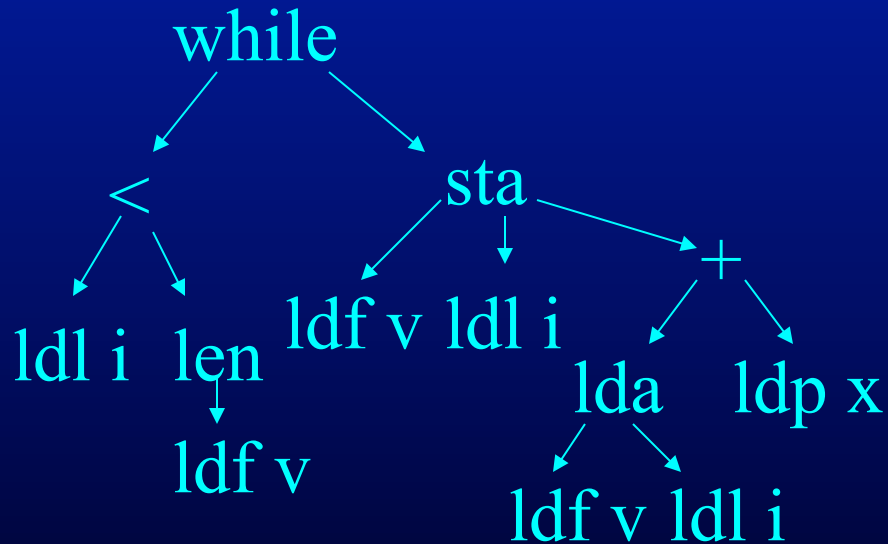


field descriptor for v   local descriptor for i   parameter descriptor for x

# Abbreviated Notation

while (i < v.length)

v[i] = v[i]+x;



# Parameter Descriptors

- When build parameter descriptor, have
  - name of type
  - name of parameter
- What is the check? Must make sure name of type identifies a valid type
  - look up name in type symbol table
  - if not there, look up name in program symbol table (might be a class type)
  - if not there, fails semantic check

# Local Descriptors

- When build local descriptor, have
  - name of type
  - name of local
- What is the check? Must make sure name of type identifies a valid type
  - look up name in type symbol table
  - if not there, look up name in program symbol table (might be a class type)
  - if not there, fails semantic check



# Local Symbol Table

- When build local symbol table, have a list of local descriptors
- What to check for?
  - duplicate variable names
  - shadowed variable names
- When to check?
  - when insert descriptor into local symbol table
- Parameter and field symbol tables similar

# Class Descriptor

- When build class descriptor, have
  - class name and name of superclass
  - field symbol table
  - method symbol table
- What to check?
  - Superclass name corresponds to actual class
  - No name clashes between field names of subclass and superclasses
  - Overridden methods match parameters and return type declarations of superclass

# Load Instruction

- What does compiler have? Variable name.
- What does it do? Look up variable name.
  - If in local symbol table, reference local descriptor
  - If in parameter symbol table, reference parameter descriptor
  - If in field symbol table, reference field descriptor
  - If not found, semantic error

# Load Array Instruction

- What does compiler have?
  - Variable name
  - Array index expression
- What does compiler do?
  - Look up variable name (if not there, semantic error)
  - Check type of expression (if not integer, semantic error)

# Add Operations

- What does compiler have?
  - two expressions
- What can go wrong?
  - expressions have wrong type
  - must both be integers (for example)
- So compiler checks type of expressions
  - load instructions record type of accessed variable
  - operations record type of produced expression
  - so just check types, if wrong, semantic error

# Type Inference for Add Operations

- Most languages let you add floats, ints, doubles
- What are issues?
  - Types of result of add operation
  - Coercions on operands of add operation
- Standard rules usually apply
  - If add an int and a float, coerce the int to a float, do the add with the floats, and the result is a float.
  - If add a float and a double, coerce the float to a double, do the add with the doubles, result is double

# Add Rules

- Basic Principle: Hierarchy of number types (int, then float, then double)
- All coercions go up hierarchy
  - int to float; int, float to double
- Result is type of operand highest up in hierarchy
  - int + float is float, int + double is double, float + double is double
- Interesting oddity: C converts float procedure arguments to doubles. Why?

# Type Inference

- Infer types without explicit type declarations
- Add is very restricted case of type inference
- Big topic in recent programming language research
  - How many type declarations can you omit?
  - Tied to polymorphism



# Equality Expressions

- If build expression  $A = B$ , must check compatibility
- B must be compatible with A
  - Can always substitute a B for an A
  - B satisfies all the requirements for an A
  - B can do at least as much as A
- Int compatible with Int
- Float compatible with Int, Int compatible with Float
- Class D compatible with Class C if D inherits from C (but not vice-versa)

# Inheritance Example - Point Class

```
class point {  
    int c;  
    int getColor() { return(c); }  
    int distance() { return(0); }  
}
```

# Point Subclasses

```
class cartesianPoint extends point{  
    int x, y;  
    int distance() { return(x*x + y*y); }  
}
```

```
class polarPoint extends point {  
    int r, t;  
    int distance() { return(r*r); }  
    int angle() { return(t); }  
}
```

# Object Interfaces

- Point - getColor(); distance();
  - CartesianPoint – getColor(); distance();
  - PolarPoint – getColor(); distance(); angle();
  - Semantic check
    - Use type declarations
    - Check that object implements every invoked method
- ```
Point p = new PolarPoint();  
p.distance(); // checks  
p.angle(); // does not check
```

# Legal and Illegal Code Sequences

- Legal code sequences
  - `Point p = new Point(); p.distance();`
  - `Point p = new CartesianPoint(); p.distance();`
  - `PolarPoint o = new PolarPoint(); o.angle();`
  - `Point p; PolarPoint o; p = o;`
- Illegal code sequences
  - `Point p = new PolarPoint(); p.angle();`
  - `Point p; PolarPoint o; o = p;`

# Store Instruction

- What does compiler have?
  - Variable name
  - Expression
- What does it do?
  - Look up variable name.
    - If in local symbol table, reference local descriptor
    - If in parameter symbol table, error
    - If in field symbol table, reference field descriptor
    - If not found, semantic error
  - Check type of variable name against type of expression
    - If variable type not compatible with expression type, error

# Store Array Instruction

- What does compiler have?
  - Variable name, array index expression
  - Expression
- What does it do?
  - Look up variable name.
    - If in local symbol table, reference local descriptor
    - If in parameter symbol table, error
    - If in field symbol table, reference field descriptor
    - If not found, semantic error
  - Check that type of array index expression is integer
  - Check type of variable name against type of expression
    - If variable element type not compatible with expression type, error

# Method Invocations

- What does compiler have?
  - method name, receiver expression, actual parameters
- Checks:
  - receiver expression is class type
  - method name is defined in receiver's class type
  - types of actual parameters match types of formal parameters
  - What does match mean?
    - same type?
    - compatible type?



# Semantic Check Summary

- Do semantic checks when build IR
- Many correspond to making sure entities are there to build correct IR
- Others correspond to simple sanity checks
- Each language has a list that must be checked
- Can flag many potential errors at compile time