MIT 6.1100
Semantic Analysis

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Error Issue

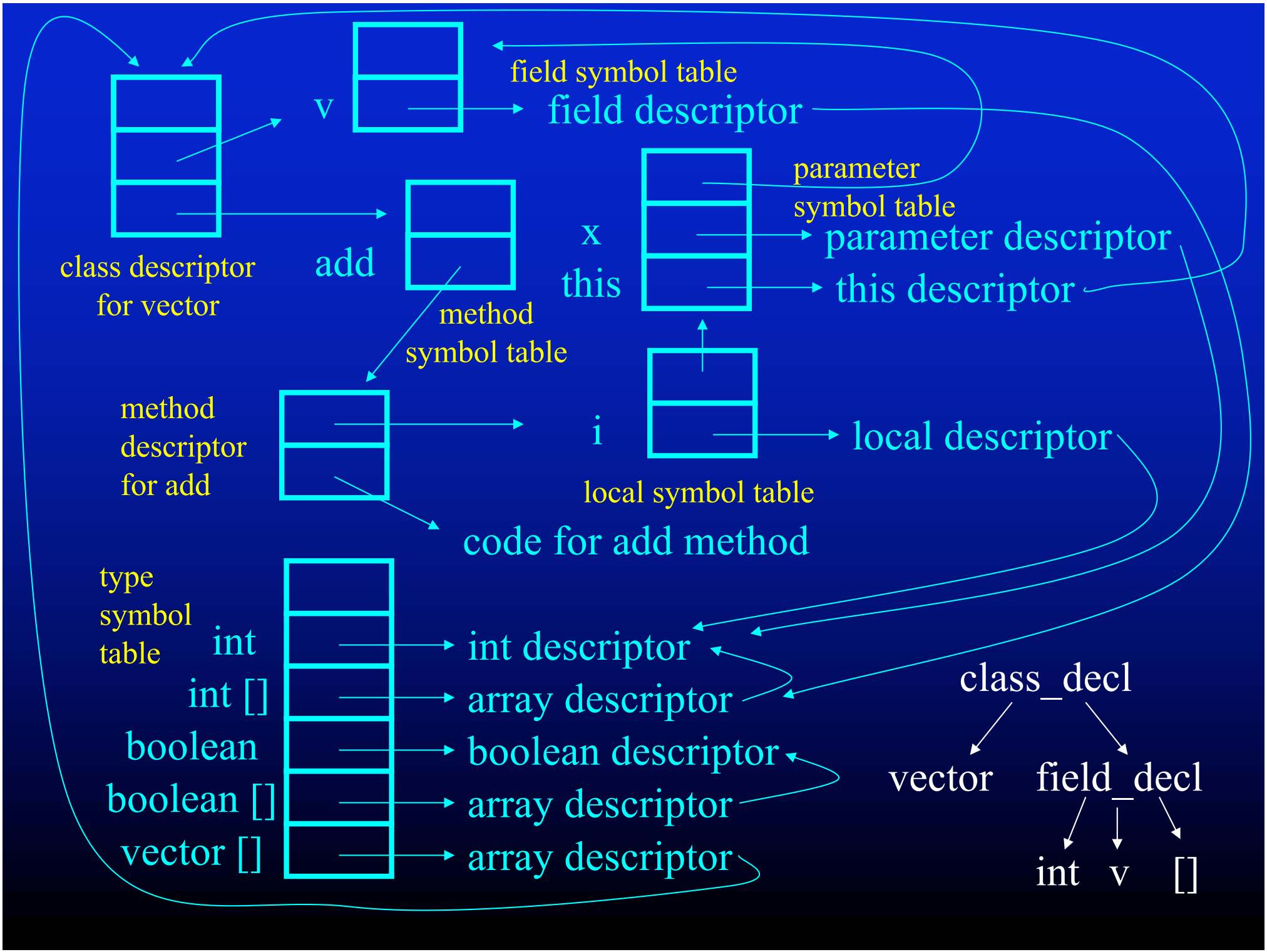
- Have assumed no problems in building IR
- But are many static checks that need to be done as part of translation
- Called Semantic Analysis

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

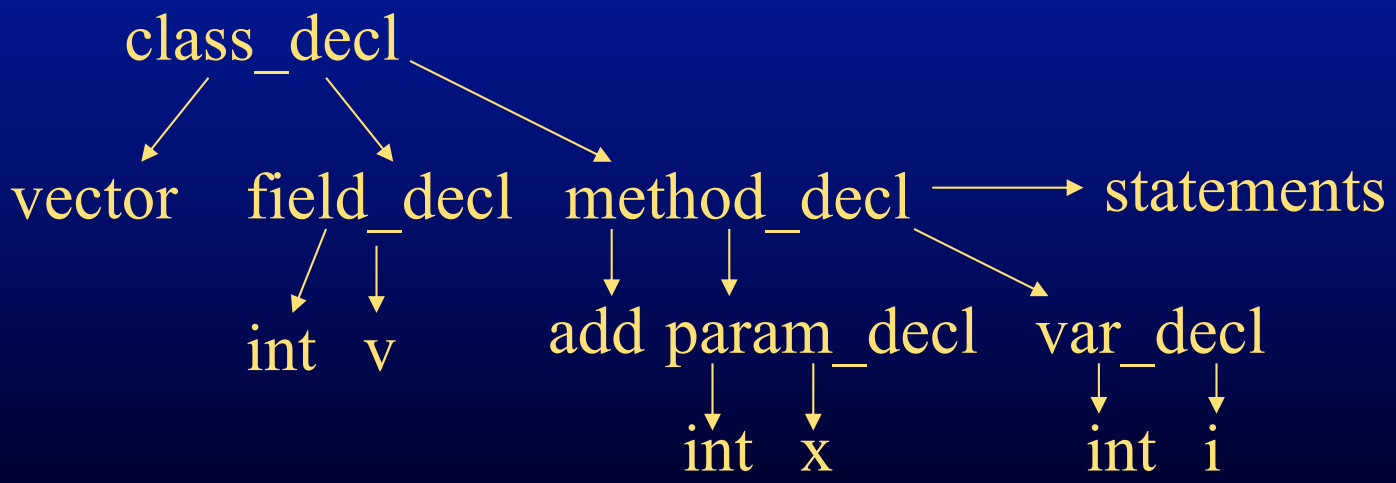
- Program Symbol Table (Class Descriptors)
- Class Descriptors
  - Field Symbol Table (Field Descriptors)
    - Field Symbol Table for SuperClass
  - Method Symbol Table (Method Descriptors)
    - Method Symbol Table for Superclass
- Method Descriptors
  - Local Variable Symbol Table (Local Variable 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

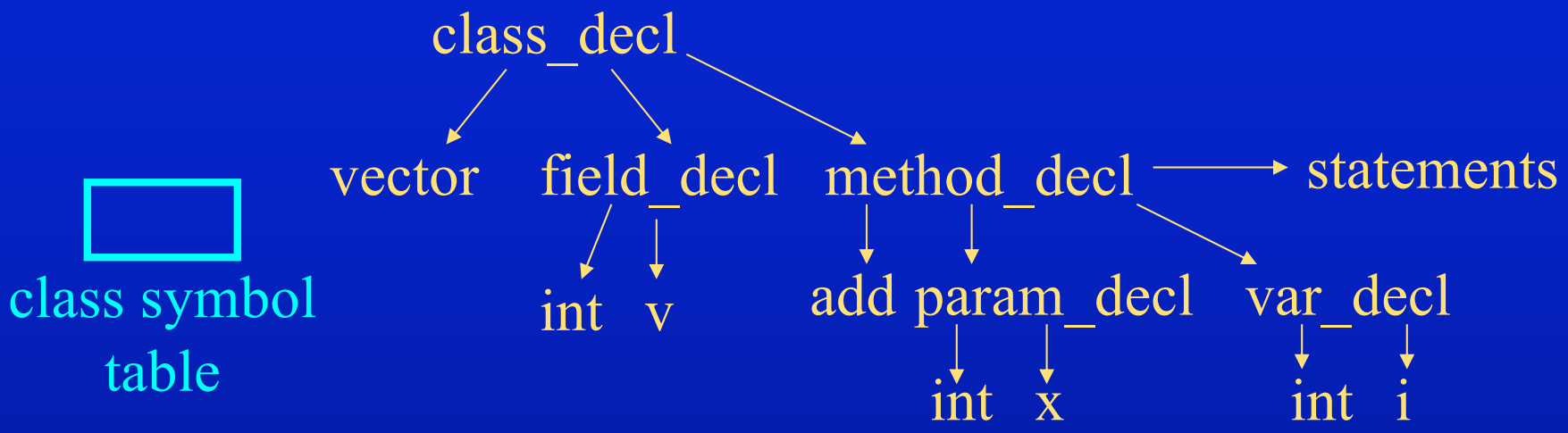

field symbol table
v
field descriptor
parameter
symbol table
x
parameter descriptor
this
this descriptor
class descriptor
for vector
add
method
symbol table
method
descriptor
for add
i
local descriptor
local symbol table
code for add method
type
symbol
table
int
int descriptor
int []
array descriptor
boolean
boolean descriptor
boolean []
array descriptor
vector []
array descriptor
class_decl
vector
field_decl
int
v
[]

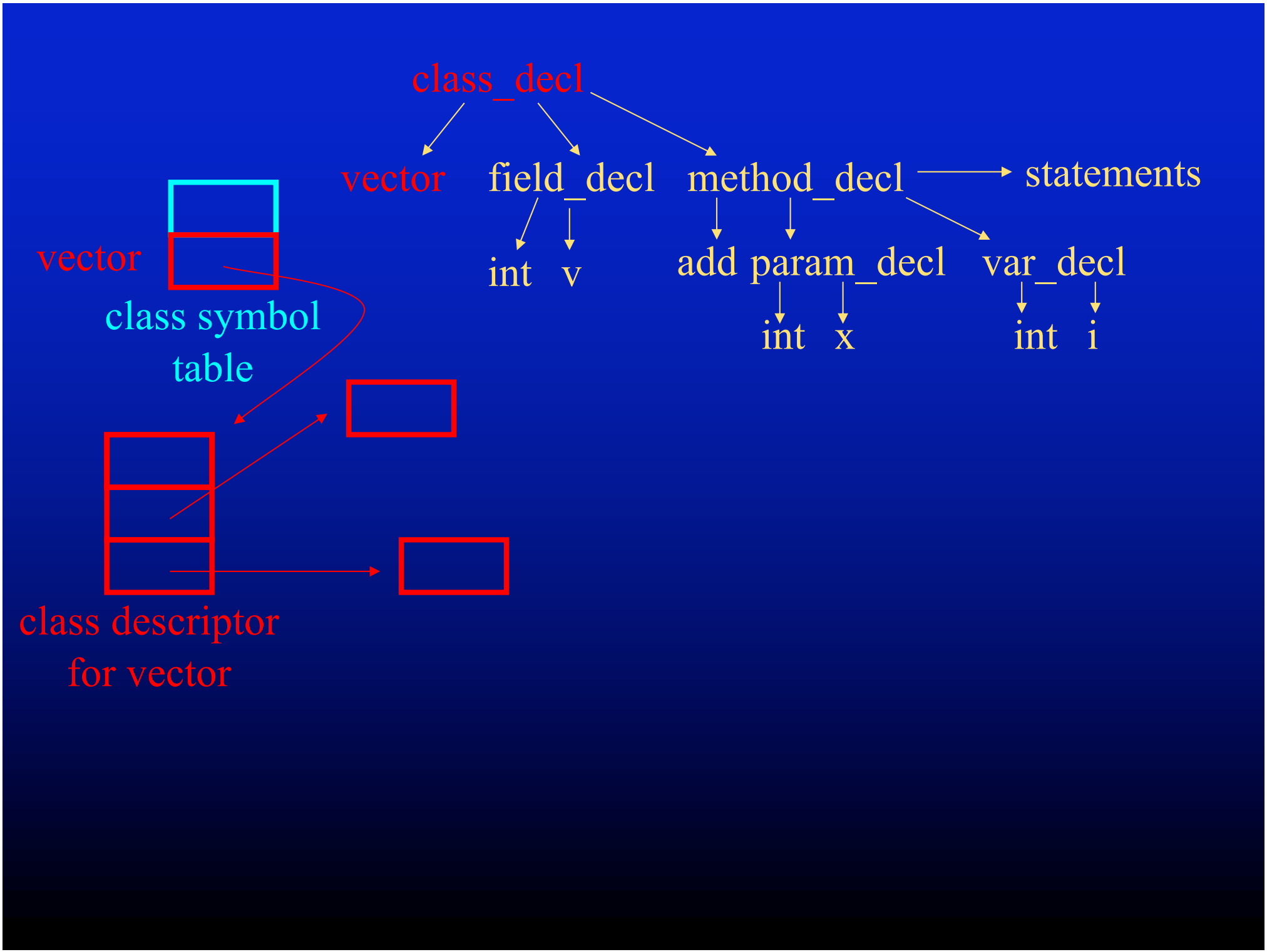
Translating from Abstract Syntax Trees to Symbol Tables

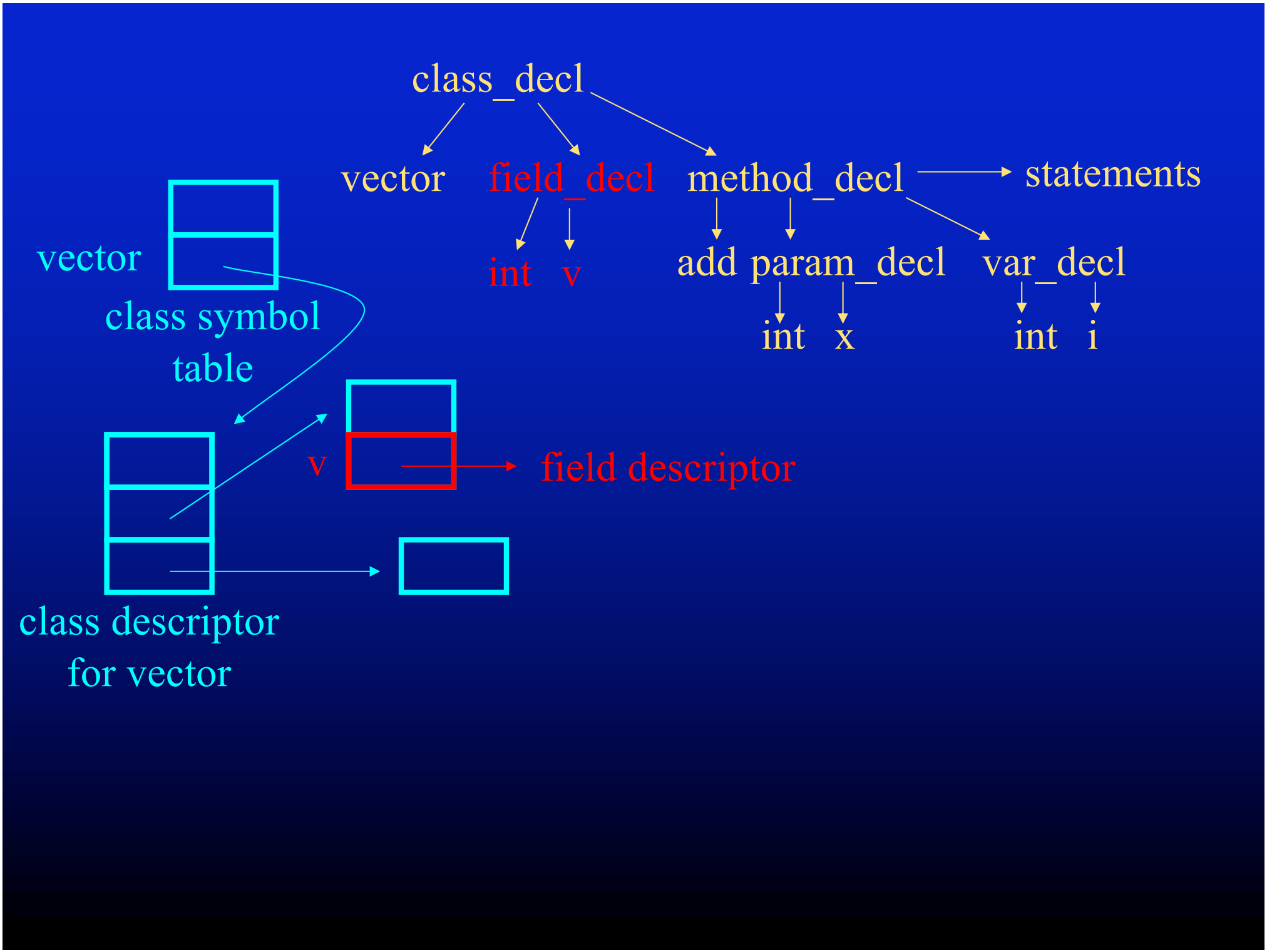
Intermediate Representation for Classes

```
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_decl
vector
field_decl
method_decl
statements
class symbol table
int
v
add
param_decl
var_decl
int
x
int
i


class_decl
vector
field_decl
method_decl
statements
int
v
add
param_decl
var_decl
int
x
int
i
vector
class symbol table
class descriptor for vector


class_decl
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field_decl
method_decl
statements
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param_decl
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int
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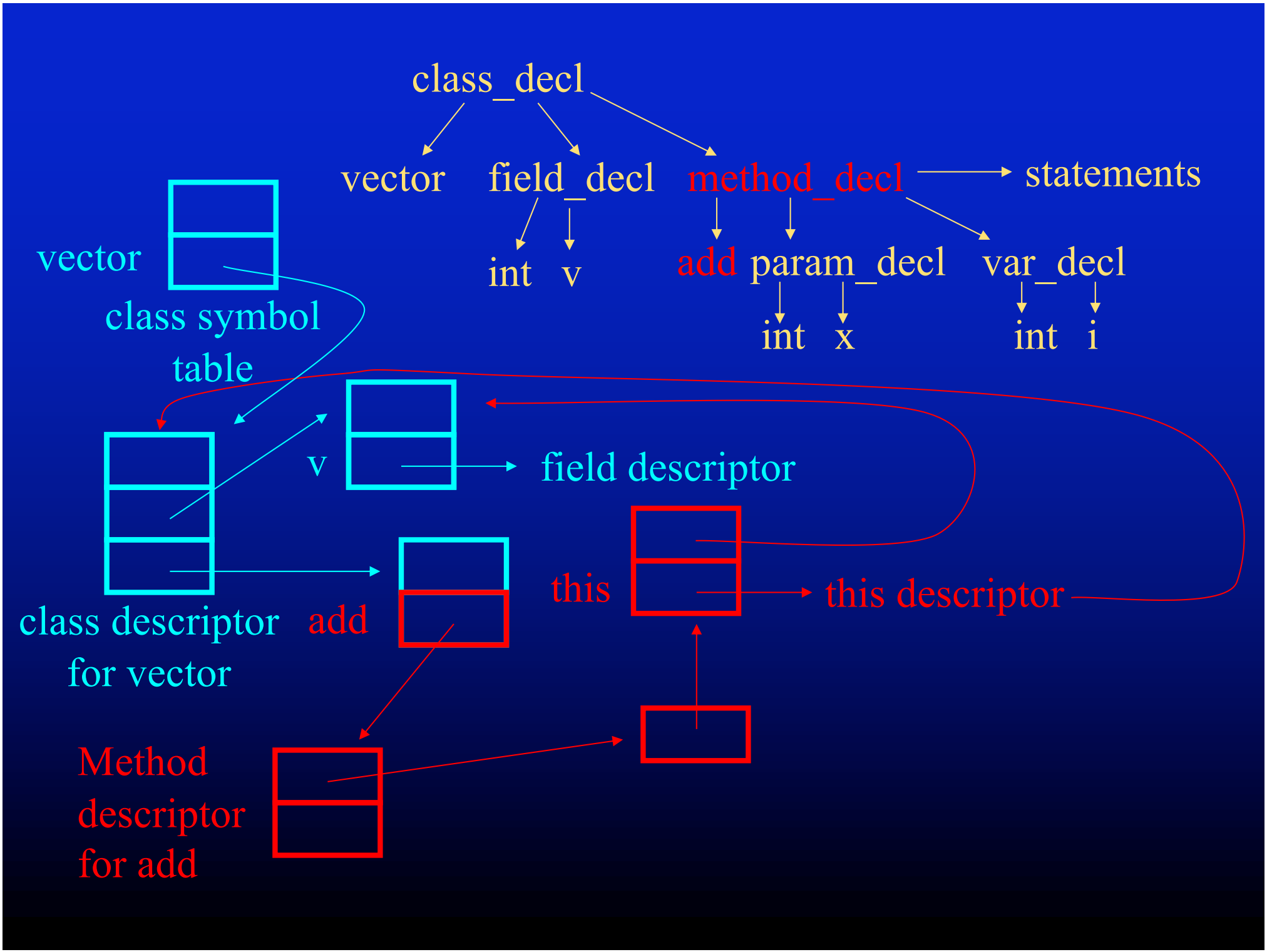
vector
class symbol
table
v
field descriptor
class descriptor
for vector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param_decl
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int
x
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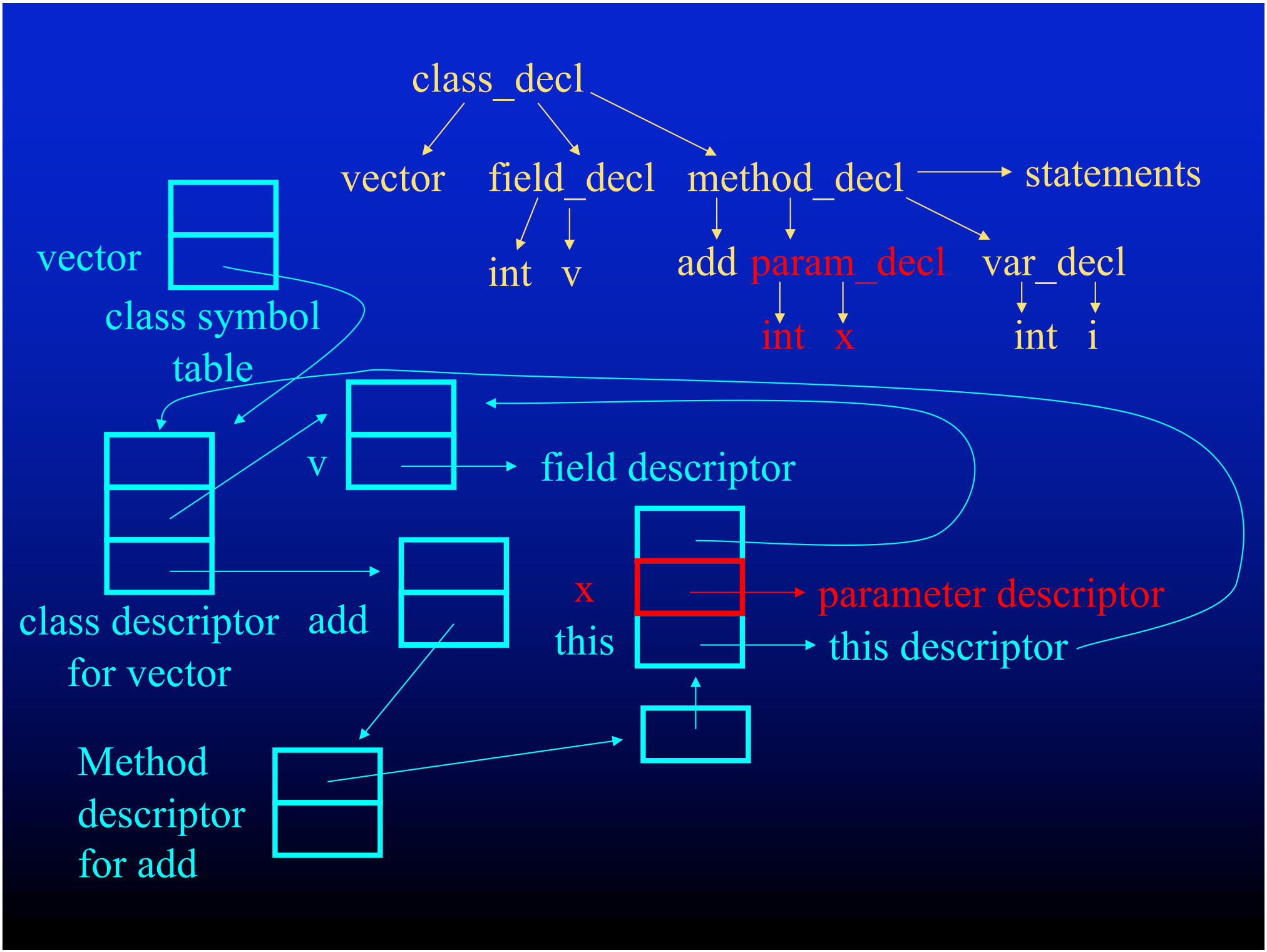
table
v
field descriptor
class descriptor
for vector
add
this
this descriptor
Method
descriptor
for add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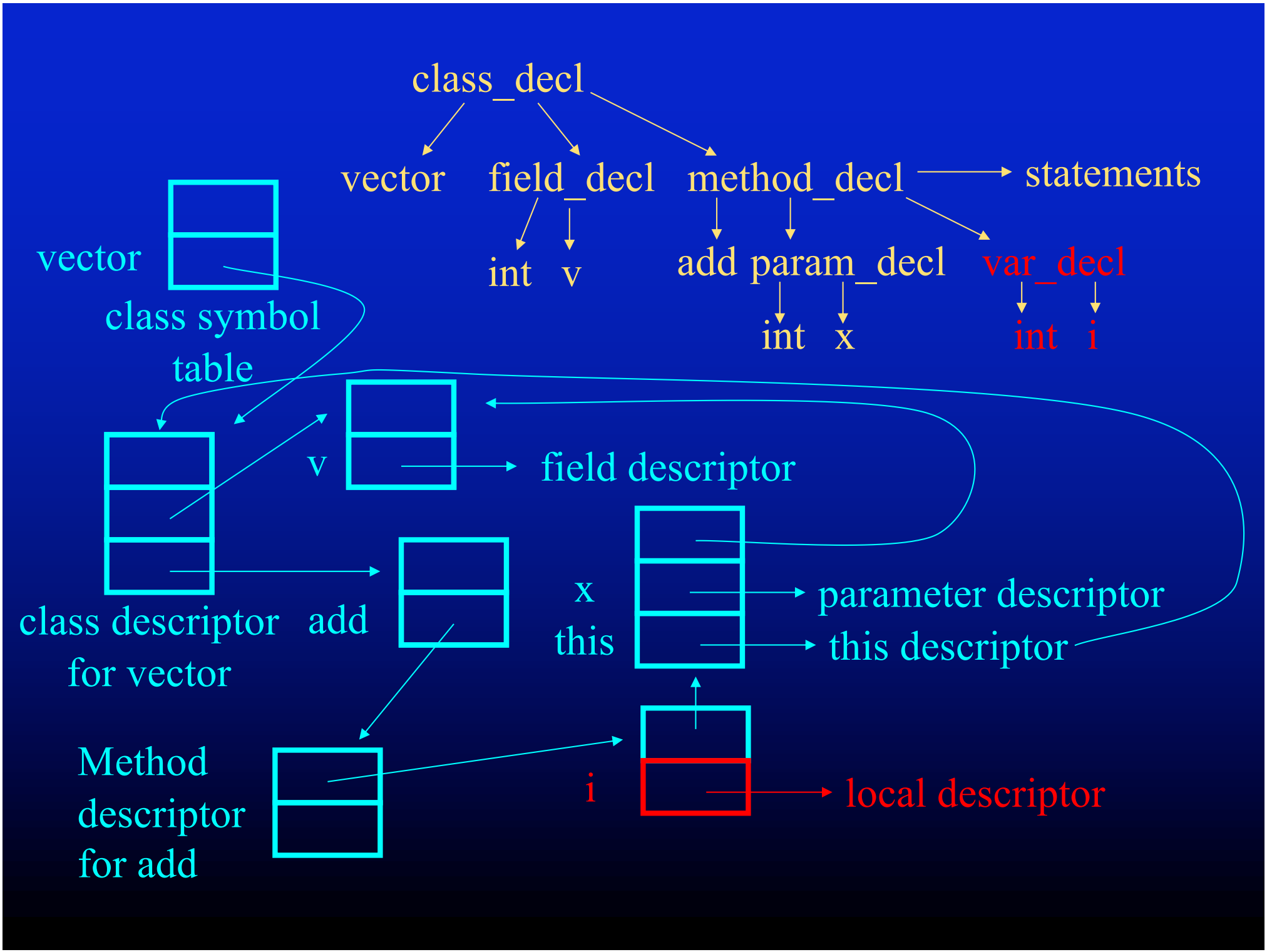
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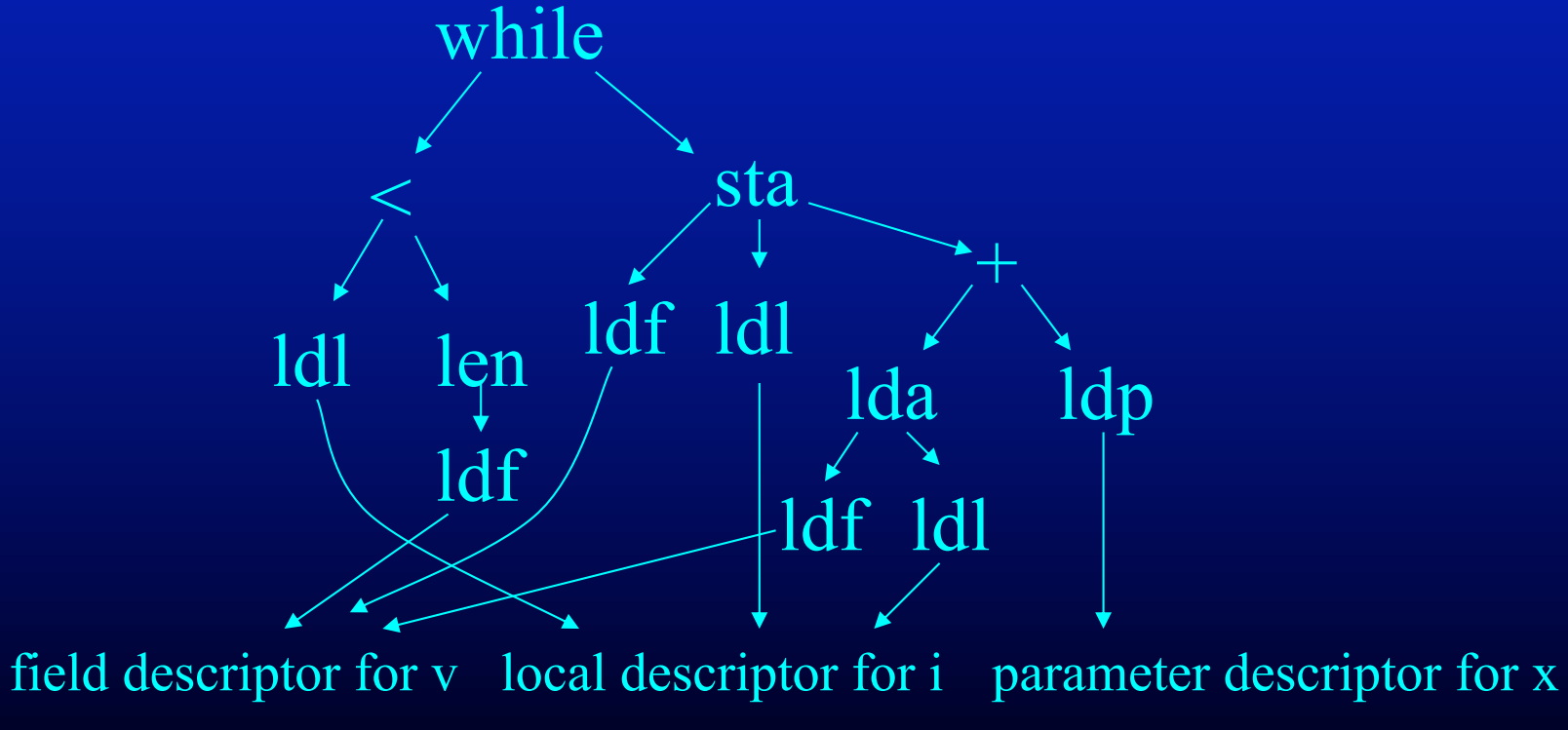
class symbol
table
v
field descriptor
class descriptor
for vector
add
x
this
parameter descriptor
this descriptor
Method
descriptor
for add
i
local descriptor

Intermediate Representation for Code

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

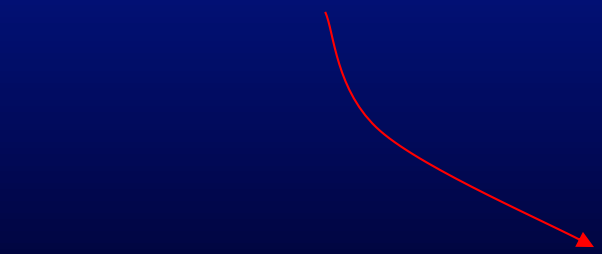


```
while (i < v.length)
    v[i] = v[i]+x;
```

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

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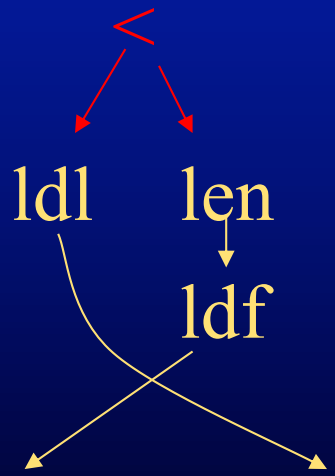

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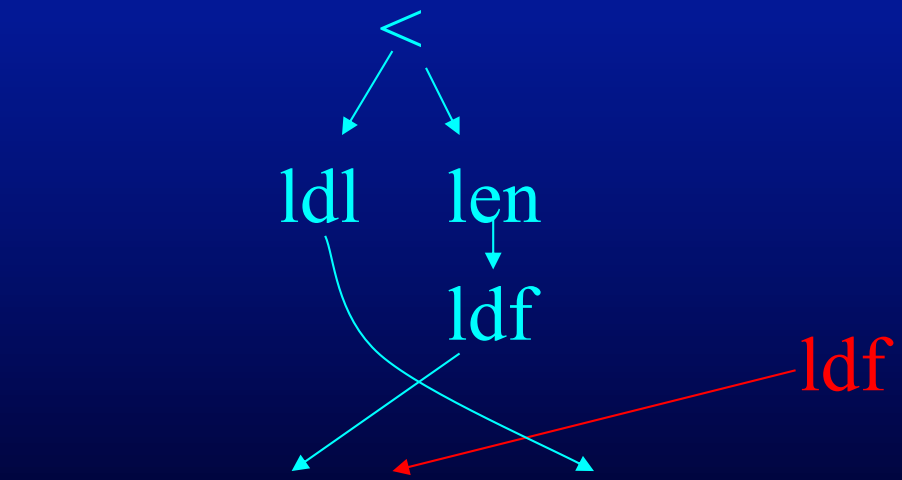

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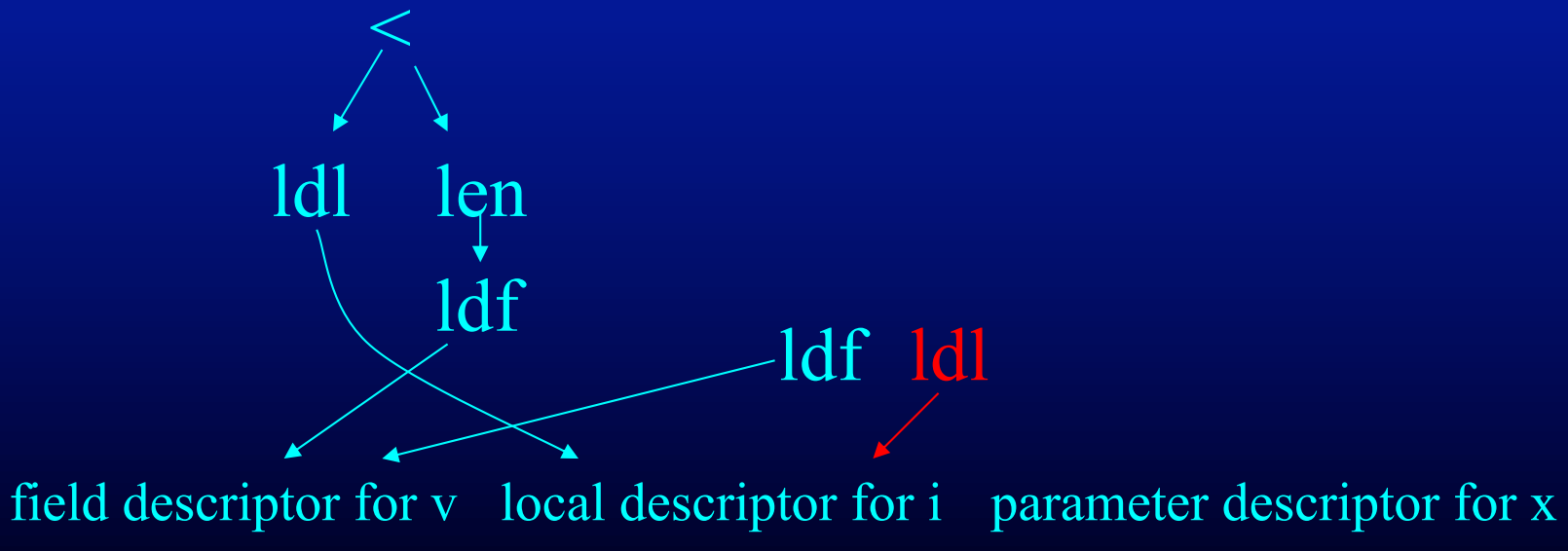

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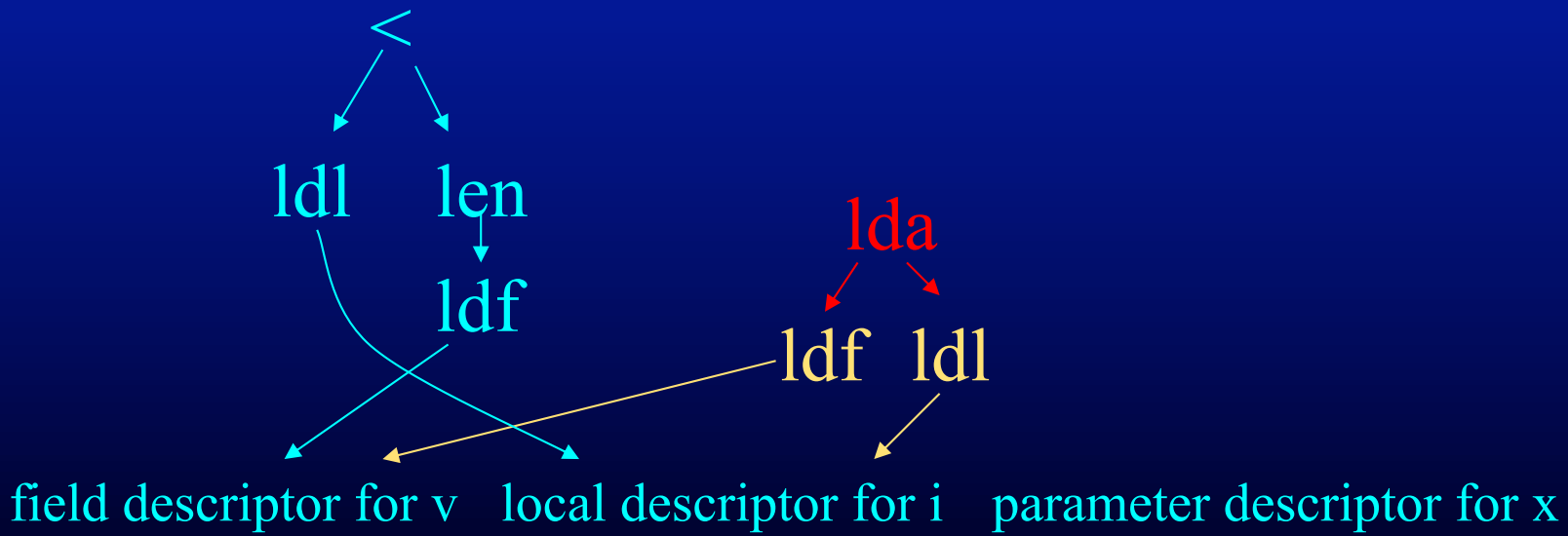

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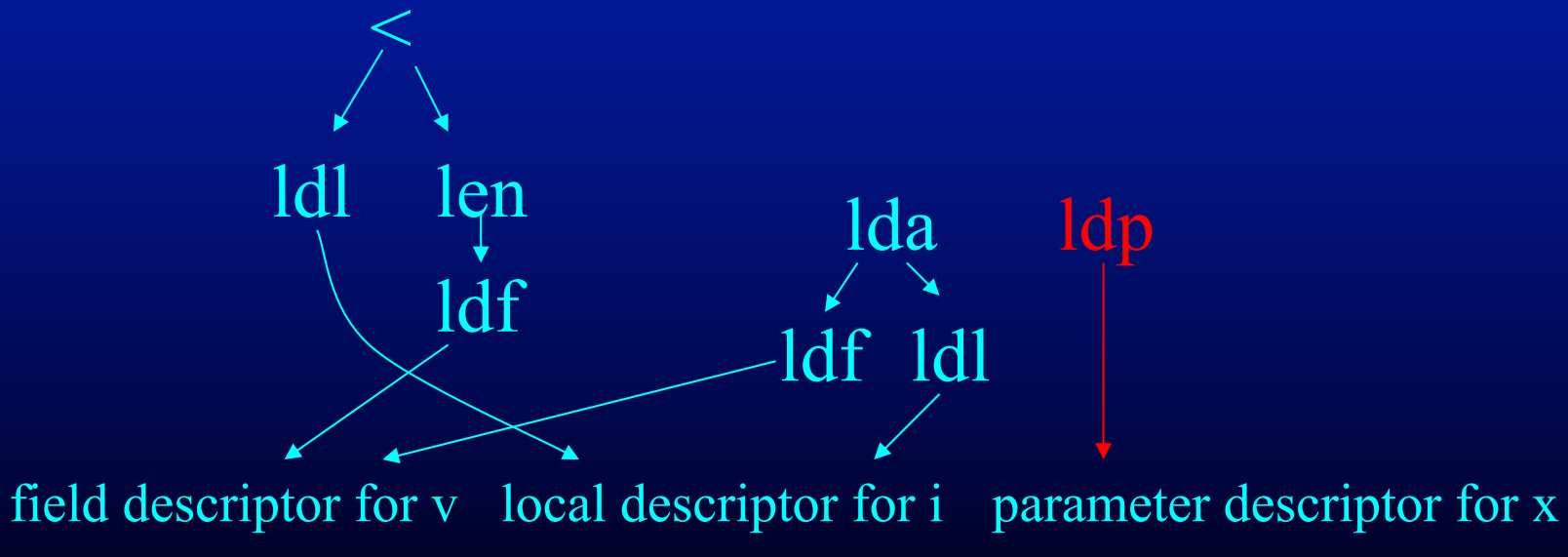
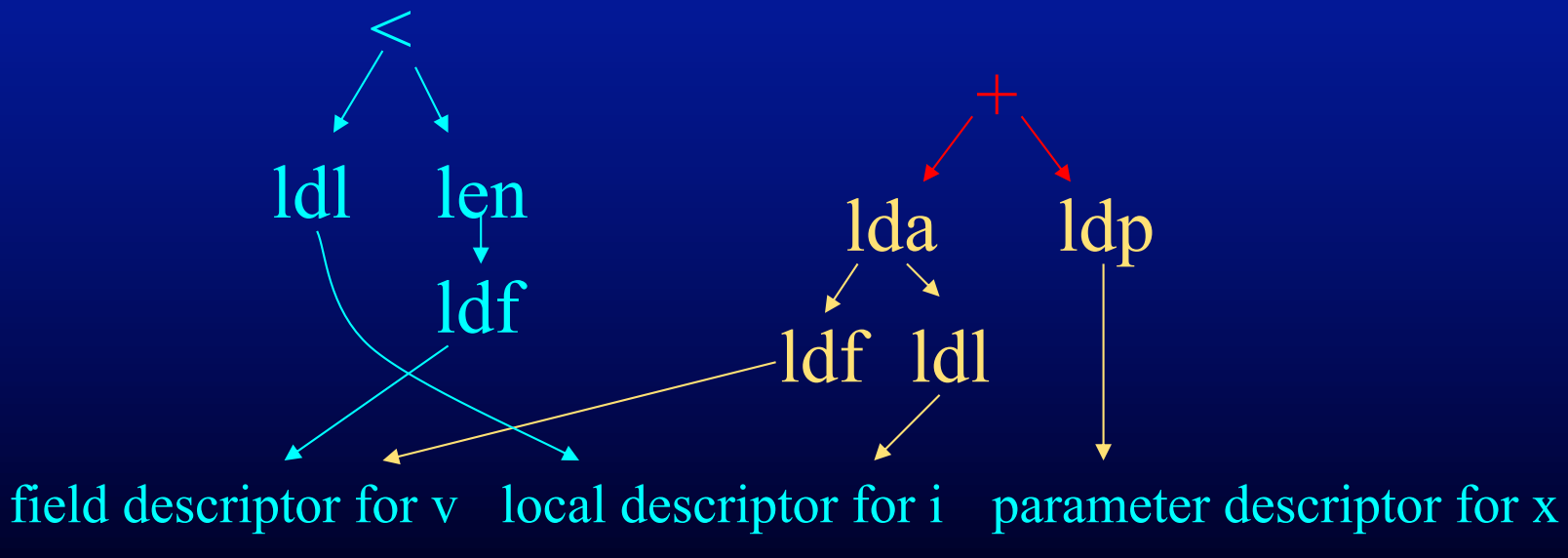


while (i < v.length)

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



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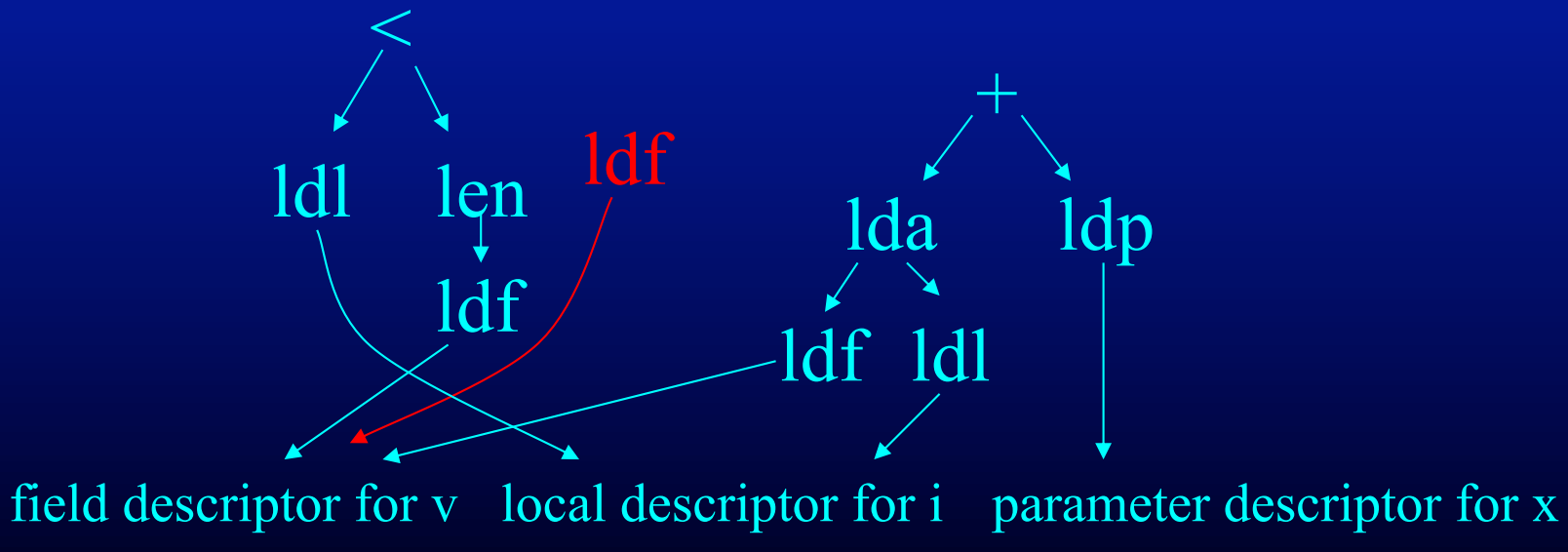

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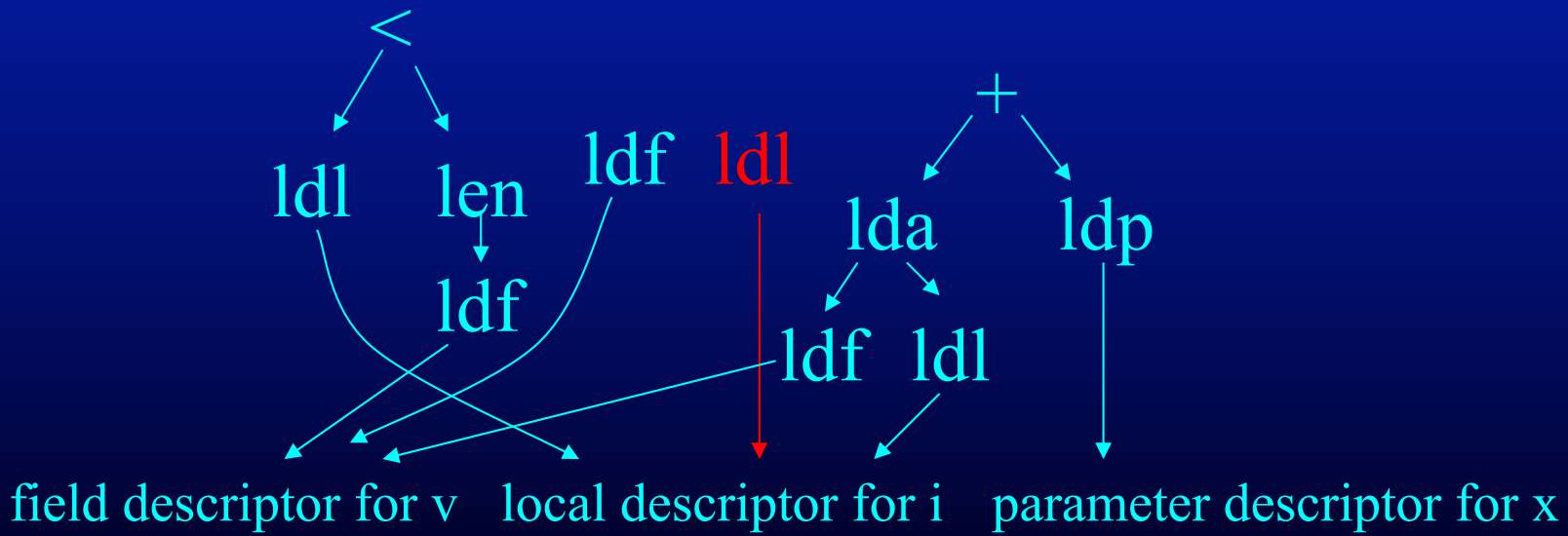

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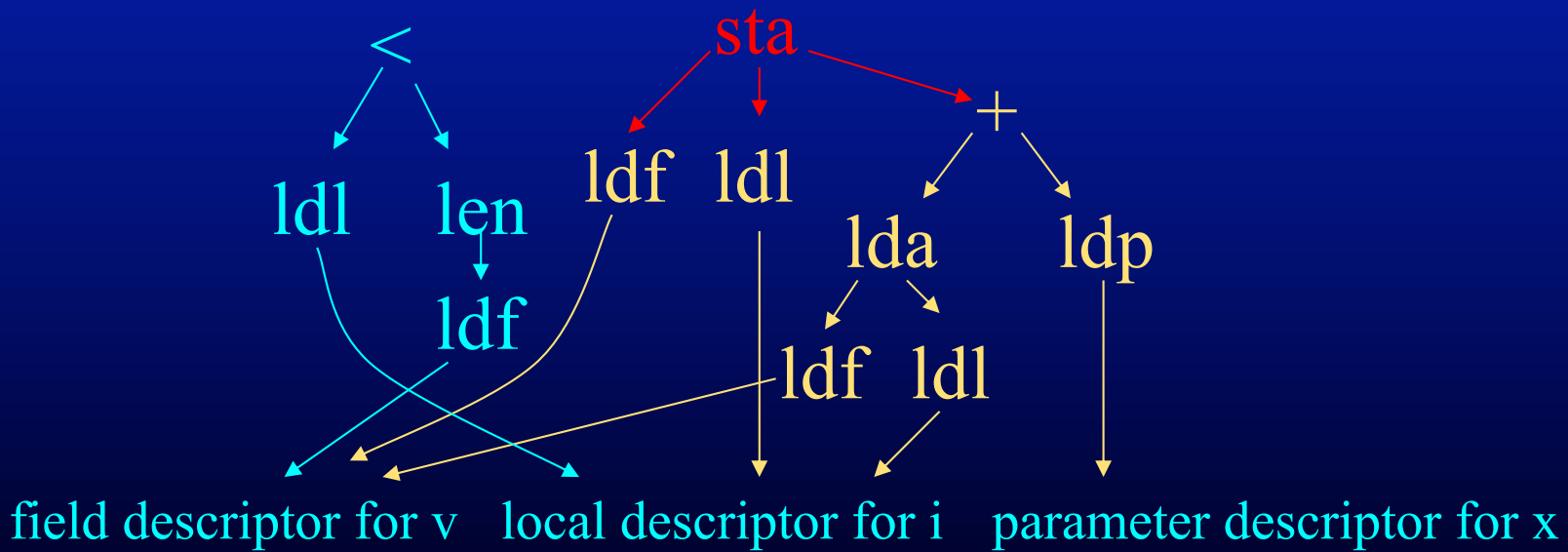

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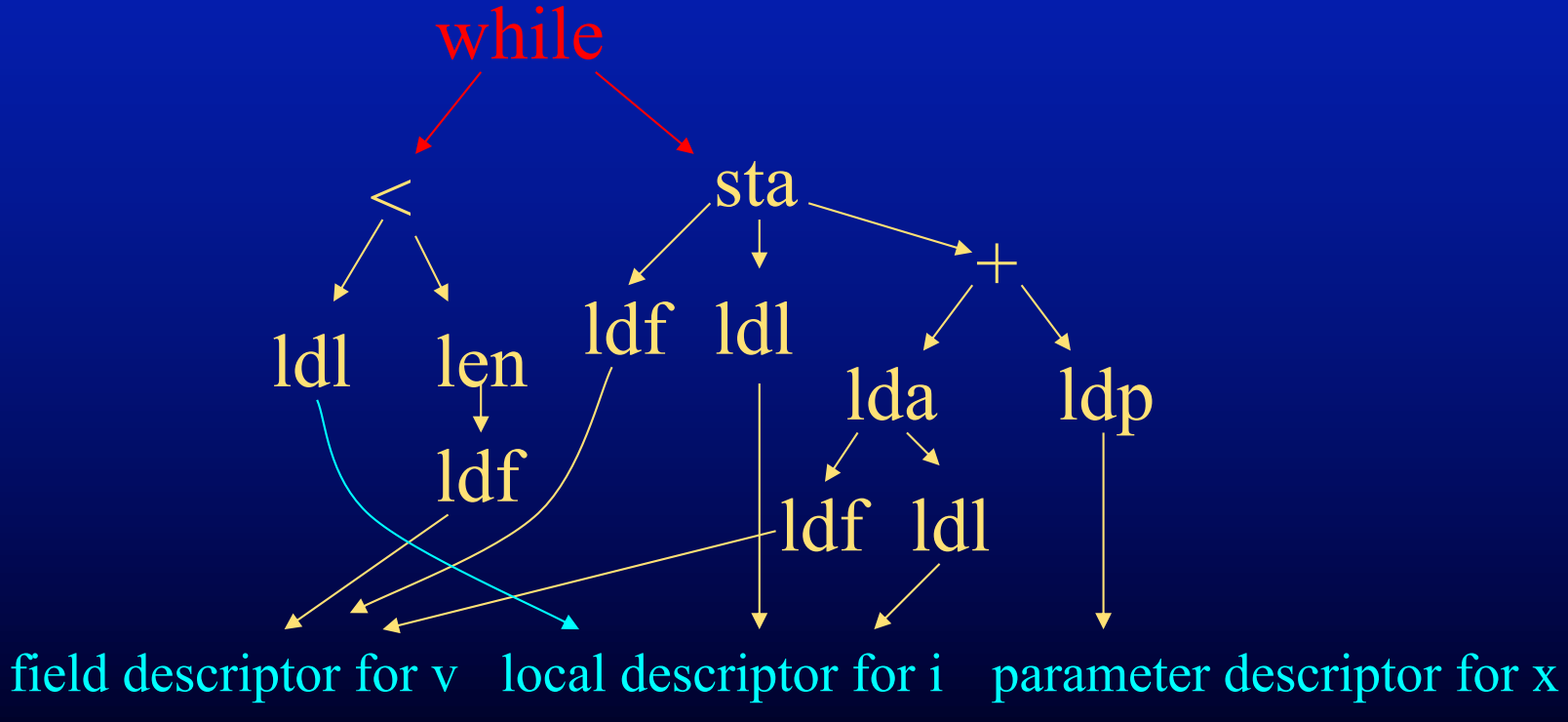

while (i < v.length)
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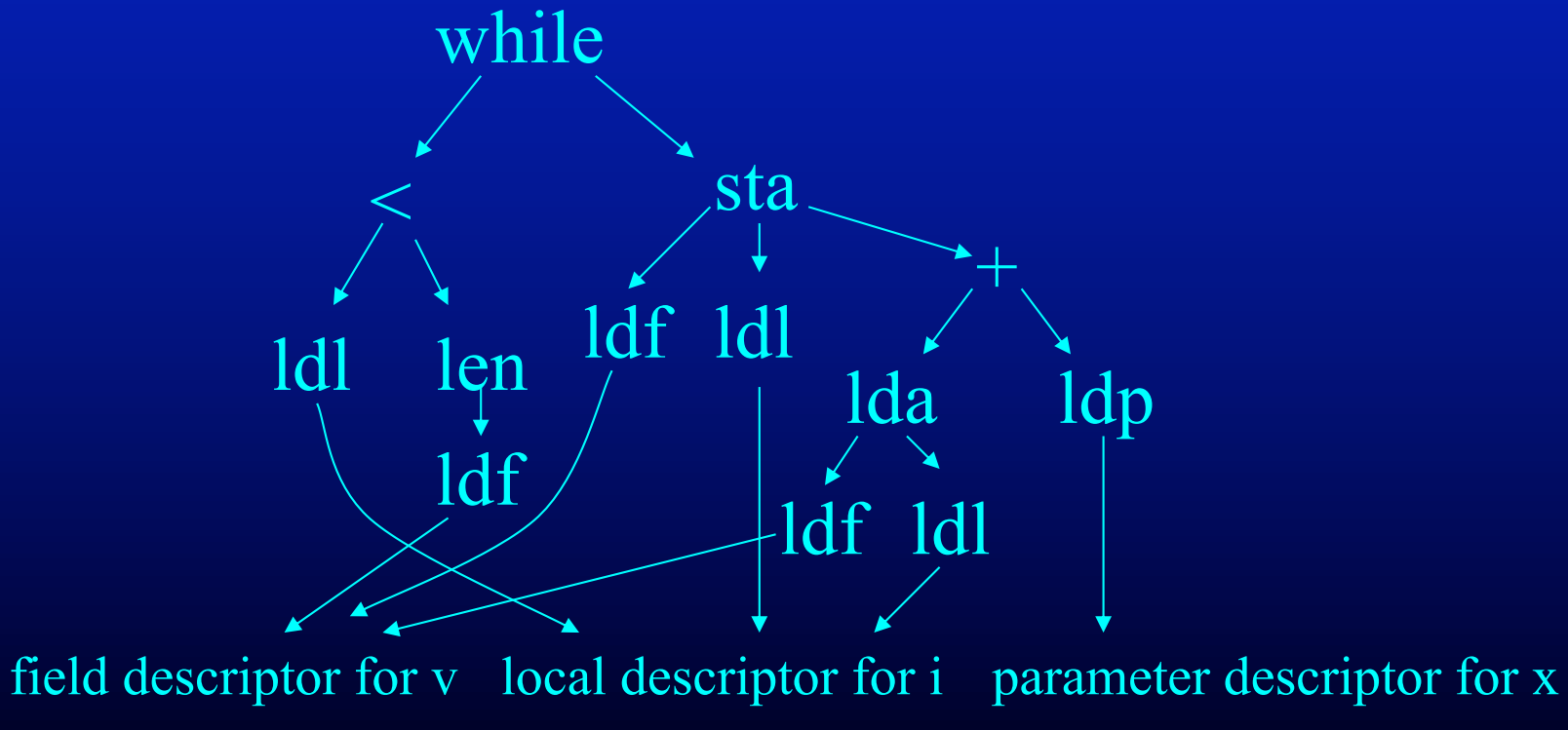
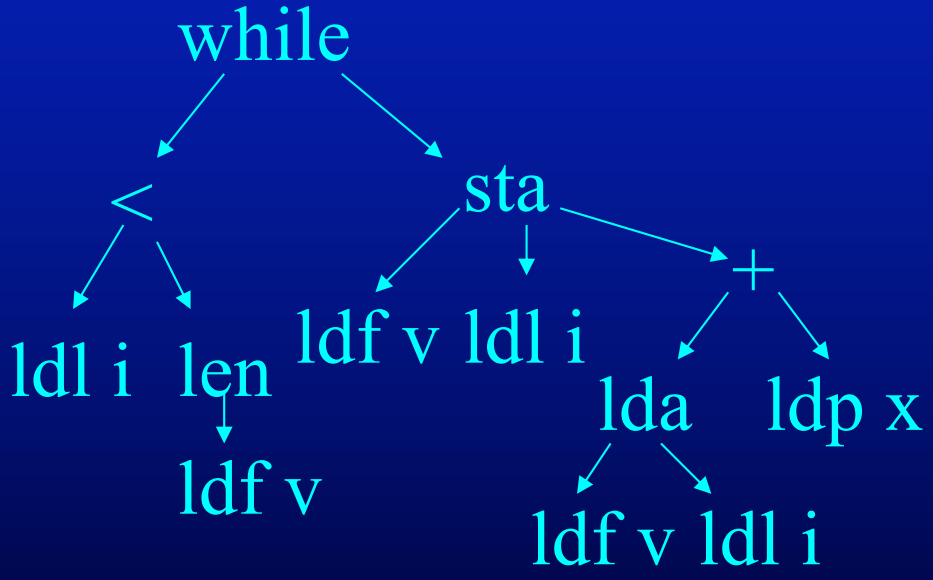


Abbreviated Notation

```
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 programming language research
  - How many type declarations can you omit?
  - Tied to polymorphism

Compatibility

- If build assigment with types A = B, must check type compatibility
- B must be compatible with A
  - Can always substitute a B in 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