CS 4120
Introduction to Compilers

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Lecture 31: Multiple Inheritance

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Field Offsets

```
class Shape {
  Point LL /* 4 */ , UR; /* 8 */
  void setCorner(int which, Point p);
}
class ColoredRect extends Shape {
  Color c; /* 12 */
  void setColor(Color c_);
}
```

- Offsets of fields from beginning are same for all subclasses
- Accesses to fields are indexed loads

  ColoredRect x;
  $\mathcal{E}[\![x.c]\!] = MEM(\mathcal{E}[\![x]\!] + 12)$
  $\mathcal{E}[\![x.UR]\!] = MEM(\mathcal{E}[\![x]\!] + 8)$

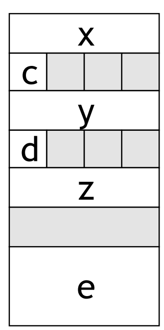
- Need to know size of superclasses – can be a problem
  - e.g., Java – field offsets resolved at dynamic link/load time

Field Alignment

- In many processors, a 32-bit load must be to an address divisible by 4, address of 64-bit load must be divisible by 8
- In rest (e.g. Pentium), loads are 10× faster if aligned -- avoids extra load

⇒ Fields should be aligned

```
struct {
   int x; char c; int y; char d;
   int z; double e;
}
```



Multiple Inheritance

- Mechanism: a class may declare multiple superclasses (C++)
- Java: may implement multiple interfaces, may inherit code from only one superclass
- Two problems: multiple supertypes, multiple superclasses
- What are implications of multiple supertypes in compiler?

Semantic problems

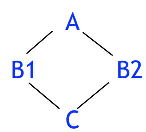
- Problem 1: ambiguity

```
class A { int m(); }
class B { int m(); }
class C extends A, B {} // which m?
```

- All methods, fields must be uniquely defined

- Problem 2: field replication

```
class A { int x; }
class B1 extends A { … }
class B2 extends A { … }
class C extends B1, B2 { … }
```



Dispatch vectors break

```
interface Shape {
   void setCorner(int w, Point p);        0
}
interface Color {
   float get(int rgb);                     0
   void set(int rgb, float value);         1
}

class Blob implements Shape, Color { …
}
```

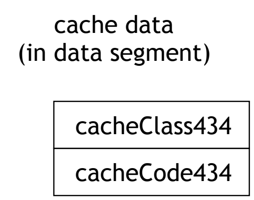

DV alternatives

- Option 1: search with inline cache (Smalltalk, Java)
  - For each class, interface, have table mapping method names to method code. Recursively walk upward in hierarchy looking for method name
  - *Optimization*: at call site, store class and code pointer in call site code (**inline caching**). On call, check whether class matches cache.

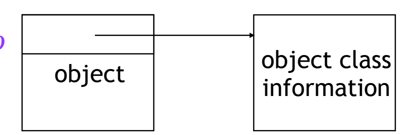
Inline cache code

- Let t_o be the receiver object:

```
  mov t1, [to]
  cmp t1, [cacheClass434]
  jnz miss
  call [cacheCode434]
miss: call slowDispatch
```



90% of calls from a site go to same code as last call from same site

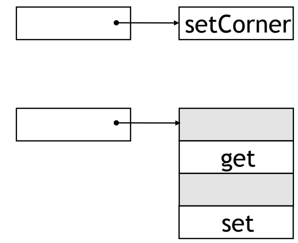


Option 2: Sparse dispatch vectors

- Make sure that two methods never allocated same offset: give Shape offset 0, Color offsets 1 and 2. Allow holes in DV!
- Some methods can be given same offset since they never occur in the same DV
- *Graph coloring* techniques can be used to compute method indices in reasonably optimal way (finding optimum is NP-complete!)

Sparse Dispatch Vectors

```
interface Shape {
        void setCorner(int w, Point p);     0
}
interface Color {
        float get(int rgb);                 1
        void set(int rgb, float value);     3
}
class Blob implements Shape, Color { ... }
```



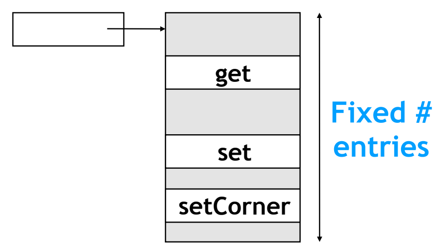
- Advantage: same fast dispatch code as SI case
- Disadvantage: requires knowledge of entire type hierarchy (makes separate compilation, dynamic loading difficult)

Option 3: Hash tables

- Idea: don't try to give all method unique indices; resolve conflicts by checking that entry is correct at dispatch
- Use hashing to generate method indices
  - Precompute hash values!
  - Some Java implementations

```
interface Shape {
        void setCorner(int w, Point p);     11
}
interface Color {
        float get(int rgb);                 4
        void set(int rgb, float value);     7
}
class Blob implements Shape, Color { ... }
```


Dispatch with Hash tables



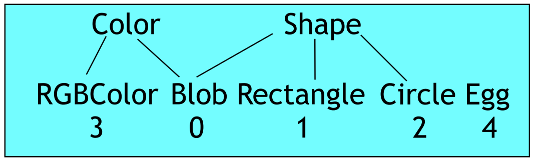
- What if there's a conflict? Entries containing several methods point to resolution code
- Basic dispatch code is (almost) identical!
- Advantage: simple, reasonably fast
- Disadvantage: some wasted space in DV, extra argument for resolution, slower dispatch if conflict

Option 5: Binary decision trees

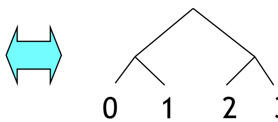
- Idea: use conditional branches, not indirect jumps
- Unique class index stored in first object word
- Range tests used to select among n possible classes at call site in lg n time – direct branches to code

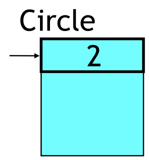
```
Shape x;
x.SetCorner(…)

mov ebx, [eax]
cmp ebx, 1
jle L1
cmp ebx, 2
je Circle$setCorner
jmp Egg$setCorner
L1: cmp ebx, 0
je Blob$setCorner
jmp Rect$setCorner
```



Decision tree





Binary decision tree

- Works well if distribution of classes is highly skewed: branch prediction hardware eliminates branch stall of ~10 cycles
  - Can use profiling to identify common paths for each call site individually
  - 90%/10% : usually a common path to put at top of decision tree

- Like sparse DVs: need whole-program analysis
- Indirect jump can have better expected execution time for >2 classes: at most one mispredict