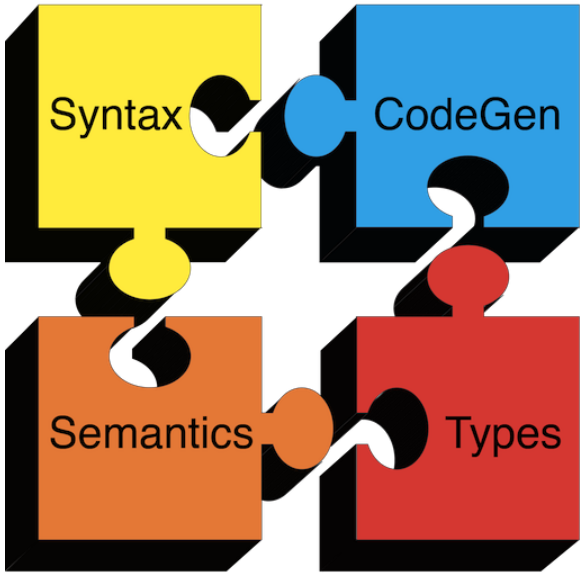


Compilers

Object Layout

Object Layout

- OO implementation = Basic code generation + More stuff
- OO Slogan: If B is a subclass of A, than an object of class B can be used wherever an object of class A is expected
- This means that code in class A works unmodified for an object of class B

Object Layout

- How are objects represented in memory?
- How is dynamic dispatch implemented?

Object Layout

```
Class A {
    a: Int <- 0;
    d: Int <- 1;
    f(): Int { a <- a + d };
};

Class  B inherits A {
    b: Int <- 2;
    f(): Int { a };
    g(): Int { a <- a - b };
};
```

```
Class  C inherits A {
    c: Int <- 3;
    h(): Int { a <- a * c };
};
```

Object Layout

```
Class A {
    a: Int <- 0;
    d: Int <- 1;
    f(): Int { a <- a + d };
};

Class  B inherits A {
    b: Int <- 2;
    f(): Int { a };
    g(): Int { a <- a - b };
};
```

```
Class  C inherits A {
    c: Int <- 3;
    h(): Int { a <- a * c };
};
```

Attributes a and d are inherited by classes B and C

Object Layout

```
Class A {
    a: Int <- 0;
    d: Int <- 1;
    f(): Int { a <- a + d };
};

Class  B inherits A {
    b: Int <- 2;
    f(): Int { a };
    g(): Int { a <- a - b };
};
```

```
Class  C inherits A {
    c: Int <- 3;
    h(): Int { a <- a * c };
};
```

All methods in all classes refer to a

Object Layout

```
Class A {
    a: Int <- 0;
    d: Int <- 1;
    f(): Int { a <- a + d };
};

Class  B inherits A {
    b: Int <- 2;
    f(): Int { a };
    g(): Int { a <- a - b };
};
```

```
Class  C inherits A {
    c: Int <- 3;
    h(): Int { a <- a * c };
};
```

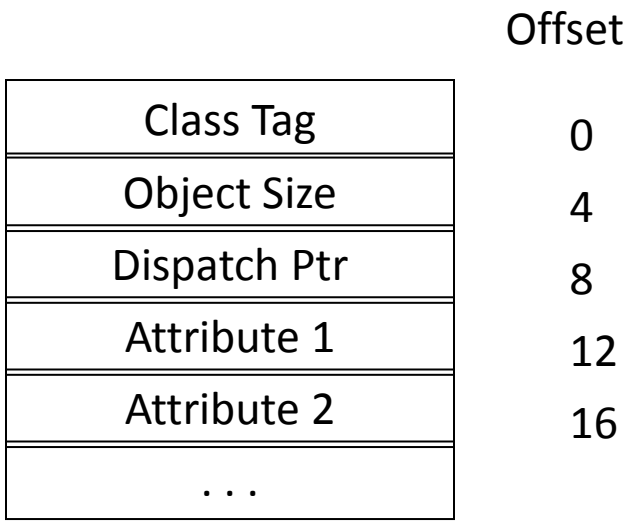
For A methods to work correctly in A, B, and C objects, attribute a must be in the same “place” in each object

Object Layout

- Objects are laid out in contiguous memory
- Each attribute stored at a fixed offset in the object
  - The attribute is in the same place in every object of that class
- When a method is invoked, the object is self and the fields are the object's attributes

Object Layout

- The first 3 words of Cool objects contain header information:



Object Layout

- Class tag is an integer
  - Identifies class of the object
- Object size is an integer
  - Size of the object in words
- Dispatch ptr is a pointer to a table of methods
  - More later
- Attributes in subsequent slots

- Lay out in contiguous memory

Object Layout

Observation: Given a layout for class A, a layout for subclass B can be defined by extending the layout of A with additional slots for the additional attributes of B

Leaves the layout of A unchanged

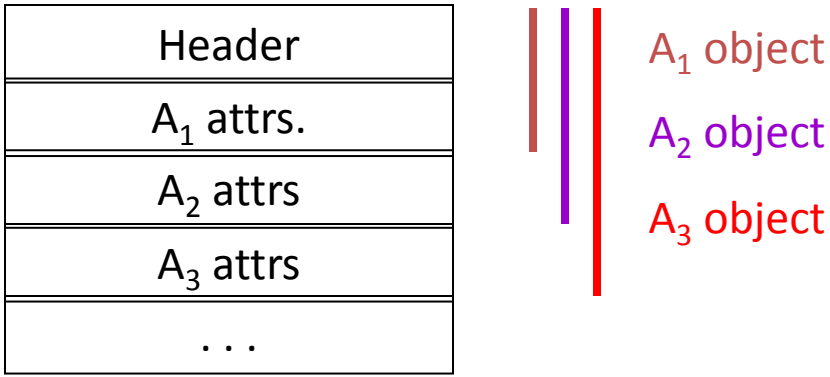
(B is an extension)

Object Layout

Offset Class	0	4	8	12	16	20
A	Atag	5	*	a	d	
B	Btag	6	*	a	d	b
C	Ctag	6	*	a	d	c

Object Layout

- The offset for an attribute is the same in a class and all of its subclasses
  - Any method for an A_1 can be used on a subclass A_2
- Consider layout for $A_n < \ldots < A_3 < A_2 < A_1$



Object Layout

For the given classes and object layout table, what are the correct inheritance relationships between classes?

- A < B < C
- C < B < A
- A < C < B
- B < C < A

```
Class  A inherits ??? {
        u: Int <- 0;
        v: Int <- 1;
};

Class  B inherits ??? {
        x: Int <- 3;
        y: Int <- 4;
};

Class  C inherits ??? {
        z: Int <- 5;
};
```

Class Tag
Object Size
Dispatch Ptr
x
y
z
u
v
. . .

Object Layout

```
Class A {
    a: Int <- 0;
    d: Int <- 1;
    f(): Int { a <- a + d };
};

Class  B inherits A {
    b: Int <- 2;
    f(): Int { a };
    g(): Int { a <- a - b };
};
```

```
Class  C inherits A {
    c: Int <- 3;
    h(): Int { a <- a * c };
};
```

Consider the dispatch

```
e.g()
```

Object Layout

```
Class A {
    a: Int <- 0;
    d: Int <- 1;
    f(): Int { a <- a + d };
};

Class  B inherits A {
    b: Int <- 2;
    f(): Int { a };
    g(): Int { a <- a - b };
};
```

```
Class  C inherits A {
    c: Int <- 3;
    h(): Int { a <- a * c };
};
```

Consider the dispatch

```
e.f ()
```

Object Layout

- Every class has a fixed set of methods
  - including inherited methods

- A *dispatch table* indexes these methods
  - An array of method entry points
  - A method f lives at a fixed offset in the dispatch table for a class and all of its subclasses

Object Layout

Offset Class	0	4
A	fA	
B	fB	g
C	fA	h

- The dispatch table for class A has only 1 method
- The tables for B and C extend the table for A to the right
- Because methods can be overridden, the method for f is not the same in every class, but is always at the same offset

Object Layout

- The dispatch pointer in an object of class X points to the dispatch table for class X

- Every method f of class X is assigned an offset O_f in the dispatch table at compile time

Object Layout

- To implement a dynamic dispatch e.f() we
  - Evaluate e, giving an object x
  - Call $D[O_f]$
    - D is the dispatch table for x
    - In the call, self is bound to x