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(Simple) Objects

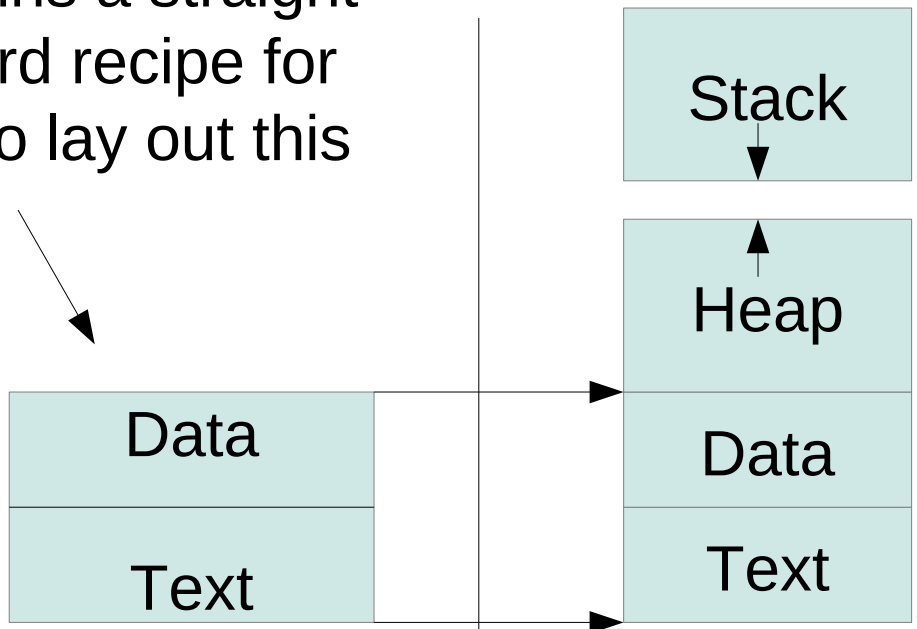
Where we were

- Last time, we looked at the details of function call mechanisms
- Object types require some extension to this, but we can cover the basics by taking a quick look at it
- That is today's topic

Process address space (again...)

Assembly program contains a straight-forward recipe for how to lay out this file

OS loader expands file to image every time program is run



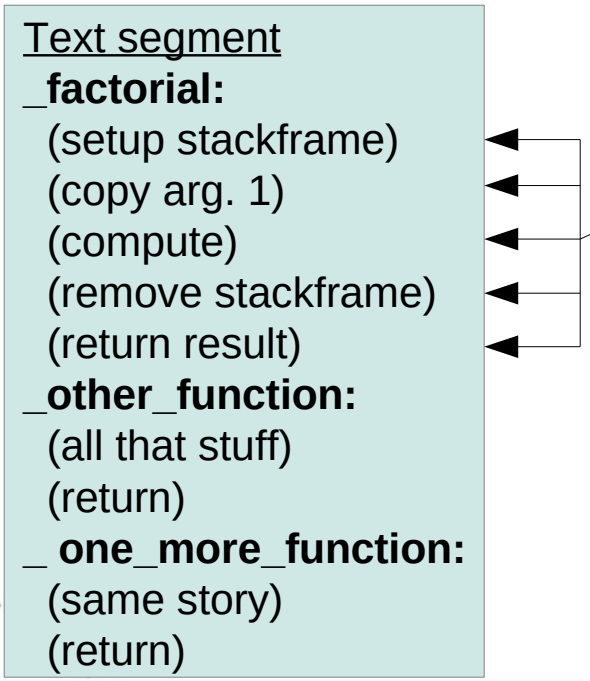
Executable file (on disk)

Run-time memory image

Code generation for functions

- Functions become labels for addresses where the subsequent instructions accept the arguments

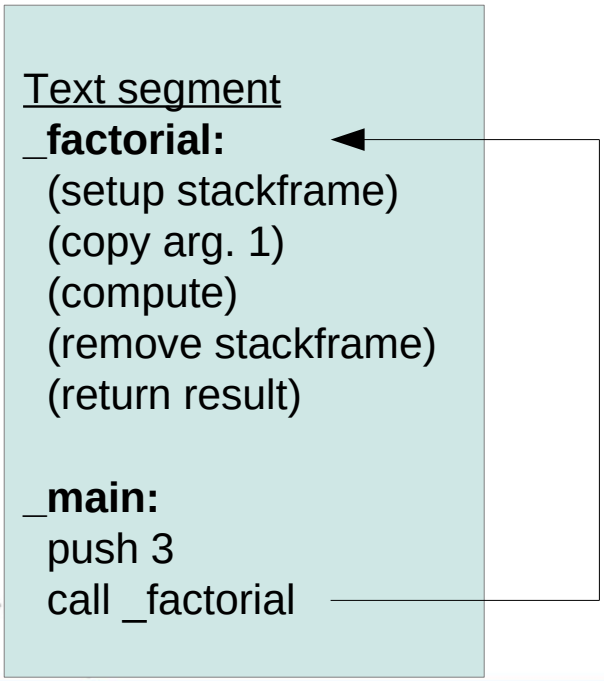
  (laid out as a stack frame matching the function's activation record)



We looked at the operations that go into these steps last time

Code generation for function calls

- Static function calls have unique names and type signatures, compiler can just push arguments in turn and insert call operation



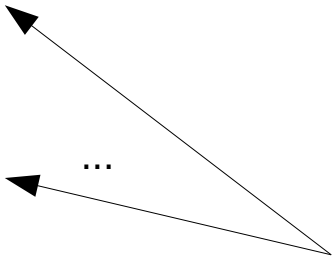
This location is mapped from a symbolic name into a target for the program counter:

1) Assembler substitutes name with symbolic adr.
2) Linker resolves adr. relative to text segment start
3) Loader maps it to actual address, visible to OS

The need for run-time dispatch

```
interface Point { int getx(); int gety(); float norm(); }
class ColoredPoint implements Point {            ...
  float norm() { return sqrt(x*x+y*y); }   ...
}
class 3DPoint implements Point {       ...
  float norm() { return sqrt(x*x+y*y+z*z); }      ...
}

Point p;
if ( cond ) p = new ColoredPoint();
else p = new 3DPoint();
float n = p.norm();
```

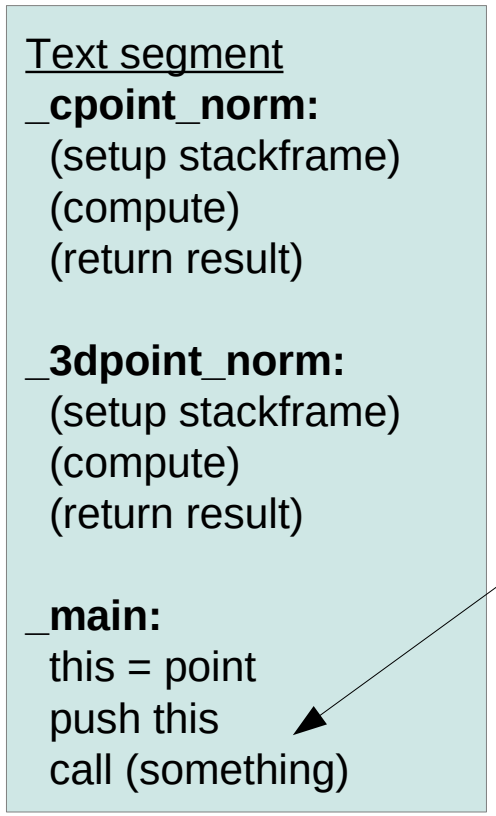


Which of these to call...

...is only known at run time

Method calls need indirection

- Even if we generate methods for each variant, the destination of a call can't be resolved once and for all...



Number the methods

- Inherited/overridden methods can share the same index

```
Class A {
  void f();              0
}
Class B extends A {
   void f();             0
   void g();             1
   void h();             2
}
Class C extends B {
   void e();             3
}
```

Each class gets a table

- Keeping the indices consistent per method,

A	
f	&a_f

B	
f	&b_f
g	&b_g
h	&b_h

C	
f	&b_f
g	&b_g
h	&b_h
e	&c_e

a call to “f” for either of these classes is a call to “method #0”

Static lookup by cast

- With an explicit cast, the table to use can be determined statically

A	
f	&a_f

B	
f	&b_f
g	&b_g
h	&b_h

C	
f	&b_f
g	&b_g
h	&b_h
e	&c_e

B my_b = new B();

((A) my_b).f() ← resolves to “call method 0 in table A”, where we find ptr. to A-s implementation of f()

Dynamic lookup by instance

- Without an explicit cast, the table to use must be determined at run time

A	
f	&a_f

B	
f	&b_f
g	&b_g
h	&b_h

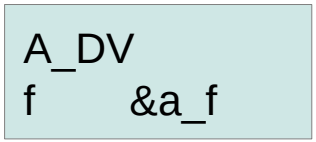
C	
f	&b_f
g	&b_g
h	&b_h
e	&c_e

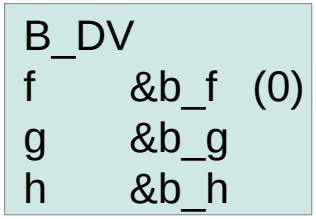
B my_b = new B();

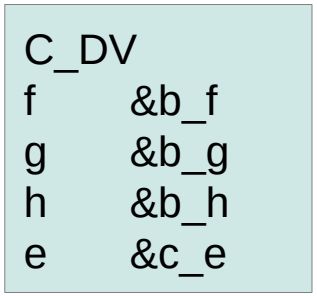
my_b.f() ← resolves to “call method 0 in table B”, where we find ptr. to B-s overridden implementation of f()

Dynamic table identification

- In order to resolve which table to use based on an object instance, the instance must be constructed with a pointer to the right table

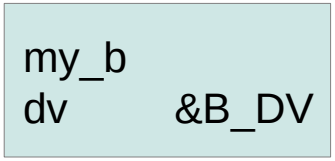






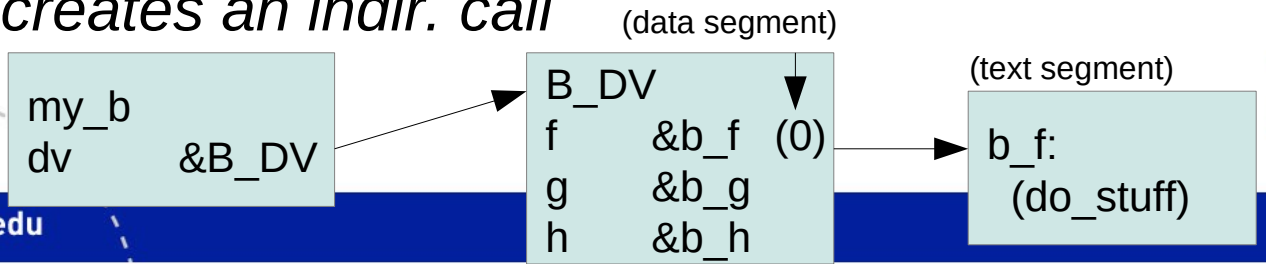
B my_b = new B(0);

creates an instance



my_b.f()

creates an indir. call



This (mildly) complicates the call mechanism

- Generated function calls go

  push param1
  push param2..
  call function

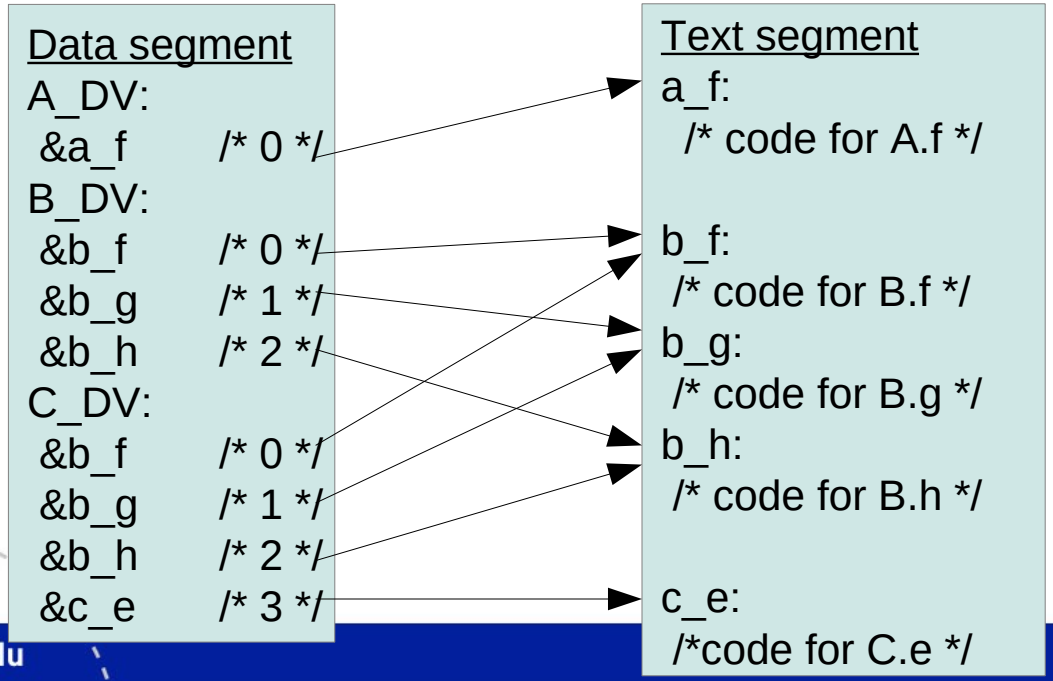
- Generated method calls go

  dv = dv_offset(this) ← 'this' is an object instance, dv is table's offset
  adr = n(dv) ← where 'n' is the method index, dv the table
  push param1
  push param2…
  push this ← implicit argument, as we discussed before
  call adr

Via this indirection, the function called will be found via the dv table an instance is constructed with

Why ‘dv’?

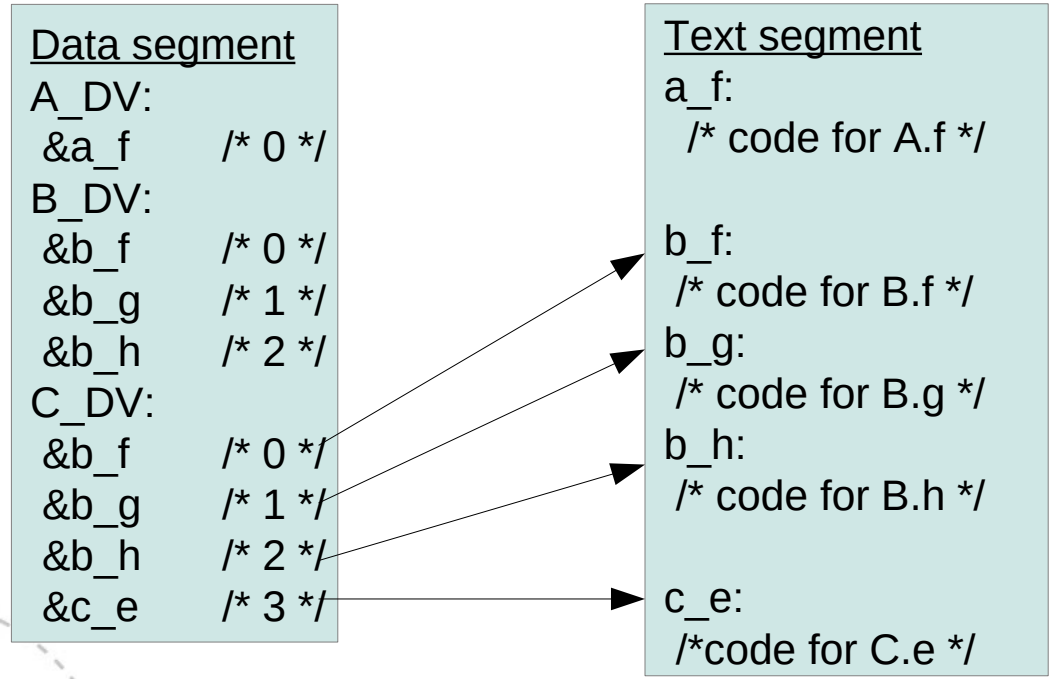
- This mechanism is called a *Dispatch Vector*
  - ...or a *dispatch table…*
  - ...or a *selector table….*
  - ...but *vector* is as good a name as any.
- All DV-s can be statically generated at compile time



(offset in table is a constant multiple of method index: all pointers have the same size...)

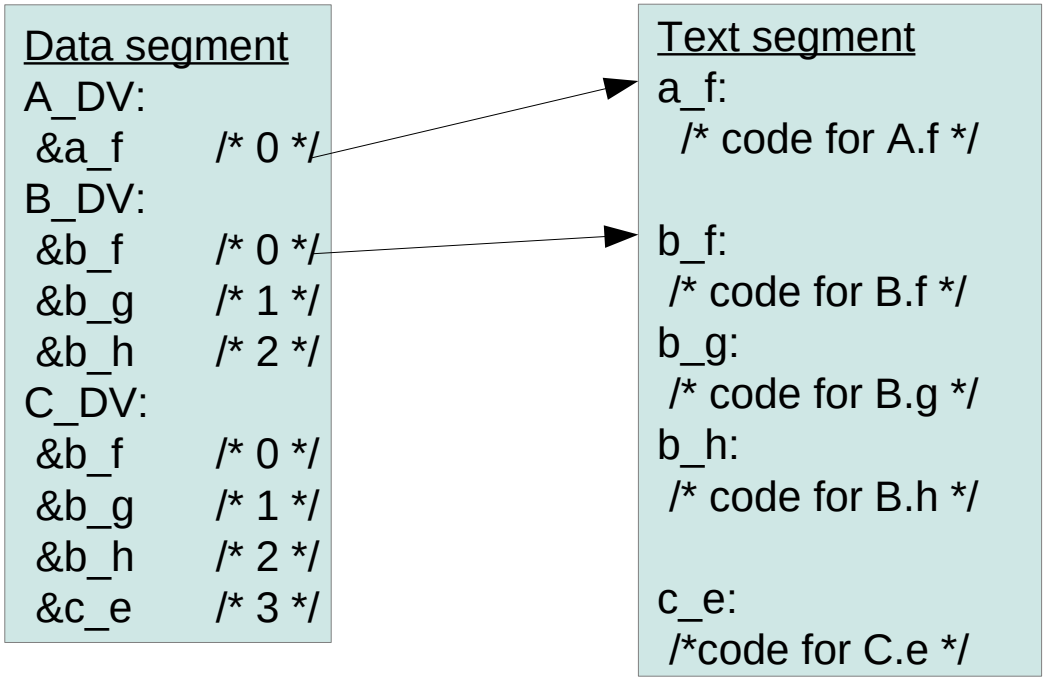
It allows inheritance

- C can get most of its methods from B
  - Syntax says it's a subclass
  - Compiler embeds that when generating the dispatch vector



It allows overriding

- B provides a different implementation of f() than A does



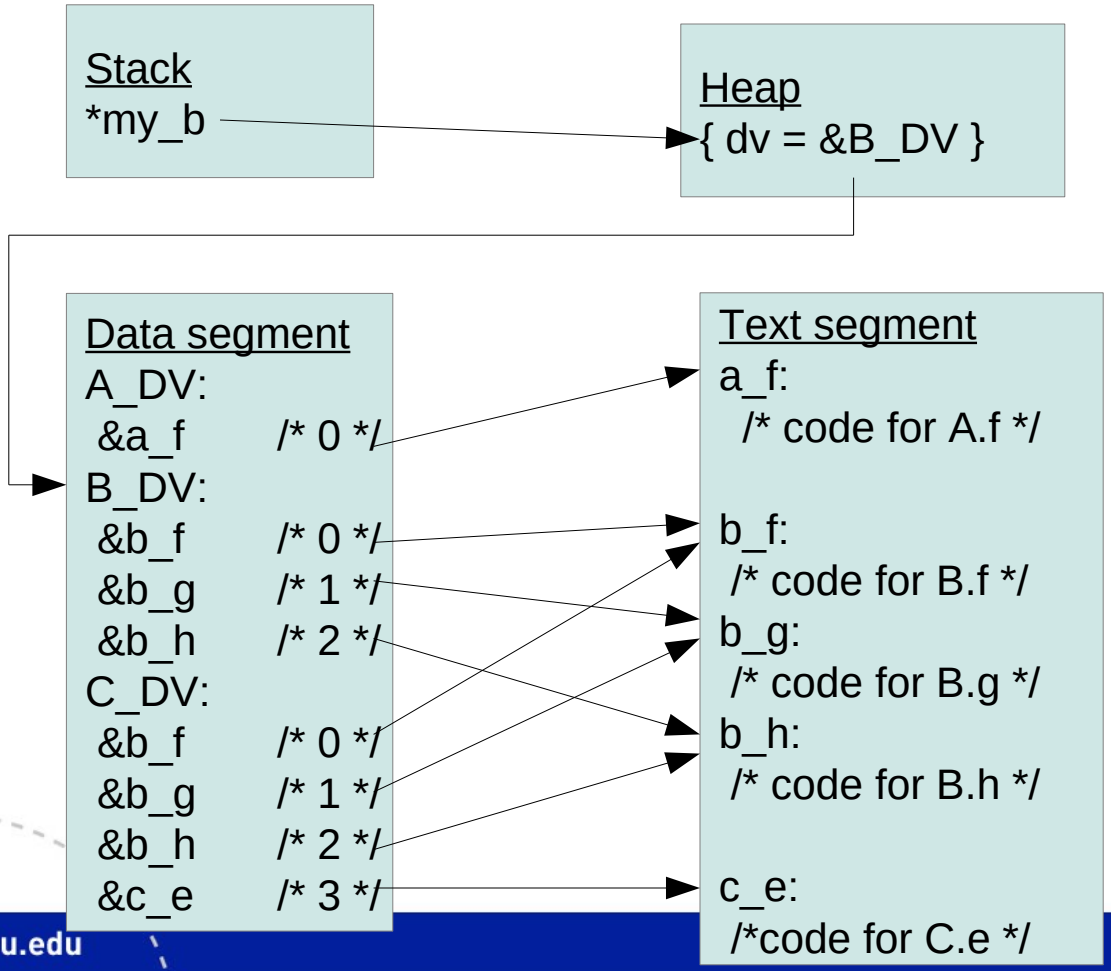
Interfaces

- This creates a natural interpretation of *interfaces* (which are classes without an implementation)
- They amount to constraints on the dispatch vector layout for classes that implement them
- They can be disposed of after compilation

- *Abstract classes* contain a dispatch vector layout and *some* specific implementations to point it at

Objects can be put on heap

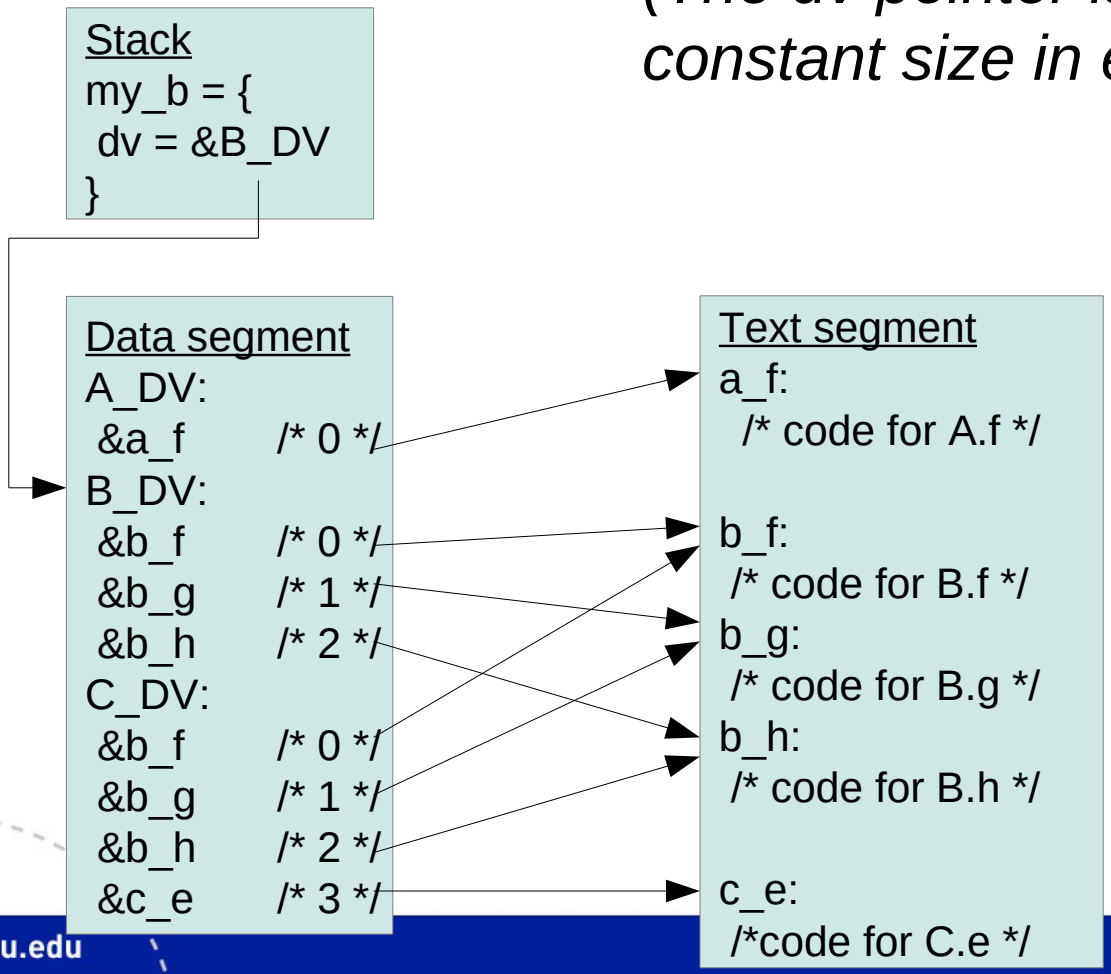
- B my_b = new B();



Objects can be put on stack

- B my_b = B();

(The dv pointer is a field of constant size in either case)



Footnote on memory access

- Fields that are not multiples of register size can be laid out densely, or with padding
  - For *e.g.* a CPU with 4-byte words,
    struct { char a; int16_t b; char c }
    can be laid out as

a	b_1	b_2	c

or alternatively,

a	0	0	0
b_1	b_2	0	0
c	0	0	0

Byte-aligned access is not always supported

- Some processors demand register-aligned adresses, so

a	b_1	b_2	c

will force the compiler to generate a fetch of the whole thing, and code to mask out and shift the elements you want

i.e. for access to b:

a	b_1	b_2	c	Load
0	b_1	b_2	0	Delete
b_1	b_2	0	0	Shift

(The code to do this can easily take more space than you save by packing data)

Byte-aligned access is slow

- Hardware-support for unaligned access typically does the load-mask-delete thing anyway
- You don’t have to write it, but it takes time (~10x)

- I’m just mentioning this because the memory-indirection scheme might indicate that dynamic dispatch adds great run-time overhead
- Memory access is expensive, but not always in a way that’s easy to expect...

Next up

- An introduction to 64-bit x86 assembly programming