Alias Analysis in LLVM

What is Alias Analysis?

Given two pointers:

- Do they always point at different memory?
- Do they always point at the same memory?
  - (miss a CSE? ;-))

Alias Analysis & Dependence Analysis

```
for (size_t i = 1; i < n; ++i) {
  p[i] = p[i - 1] * 3;
}
```

LLVM's Alias Anslysis API

Location, Location, Location

Pointer
Size
TBAA tag

Sizes are given in address units (bytes usually)

AliasAnalysis.h basics

alias

- 2 Locations

getModRefInfo and getModRefBehavior

pointsToConstantMemory

The language of alias

NoAlias = can reorder*
MustAlias = redundant load, dead store

MayAlias = I don't know

PartialAlias = Inexact overlap
    (Perhaps this should be renamed?)

LLVM IR features

noalias

- arguments *and* return values

tail

nocapture

readonly, readnone

getelementptr (aka gep)

- gep(p, 0) vs gep(0, p)

inttoptr, ptrtoint

- no guessing!

A tale of two pointer arithmetics

```
%p = gep %base, %n
```

```
%x = inttoptr %base
%y = add %x, %n
%p = ptrtoint %y
```

LLVM IR non-features

Union types
Typed memory

`restrict` anywhere but function arguments

`restrict` on a struct member

Real multi-dimensional array access
Multiple "variables" in one allocation

AA Implementations

BasicAA
SCEV-AA?
TBAA
Globals ModRef
etc.

Implementation infrastructure

The theory: Multiple chained analyses

NoAlias or MayAlias = best possible answer

MayAlias = I don't know, keep looking

PartialAlias = stop looking

BasicAA

```
%a = getelementptr @Z, 10
%b = bitcast %a to float*
%c = select i1 %p, %b, %x
%d = phi [ ... %c ... ]
%e = getelementptr %d, %n
```

Start at the bottom, find the identified object (s)

SCEV-AA

An interesting concept hack.
BasicAA can now do most of this.

Also, how do we keep the ScalarEvolution analysis up to date?

Globals Mod/Ref

Global Variables are Values, with use lists.

- Use-list escape analysis
- Check for read-only, etc.

NoAA

Says "I don't know" to all queries.

What about Andersen's?

stateful alias analyses

compile time

TBAA

Pointers to different "types" don't alias.

TBAA: "Tibah", from the Vulcan

T'PAU

just kidding

TBAA (in C)

Introduced in C89, refined in C99

C++ inherited the C89 version and made its own adaptations.

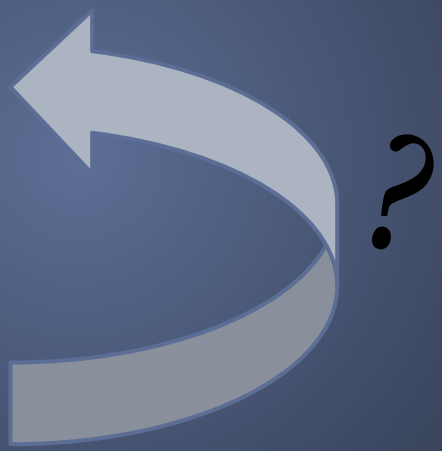
```
int *a = ???;
float *b = ???;
```

Practical TBAA

It's all about the lvalues

TBAA in C, the dark side

```
void foo(int *x, float *y) {
  *x = 1;
  int i = *x;
  *y = 1.0f;
  float f = *y;
  use(i, f);
}
```



TBAA in C++?

For C types, the same problems as C

However, virtual classes are more constrained!

Maybe?

TBAA in LLVM

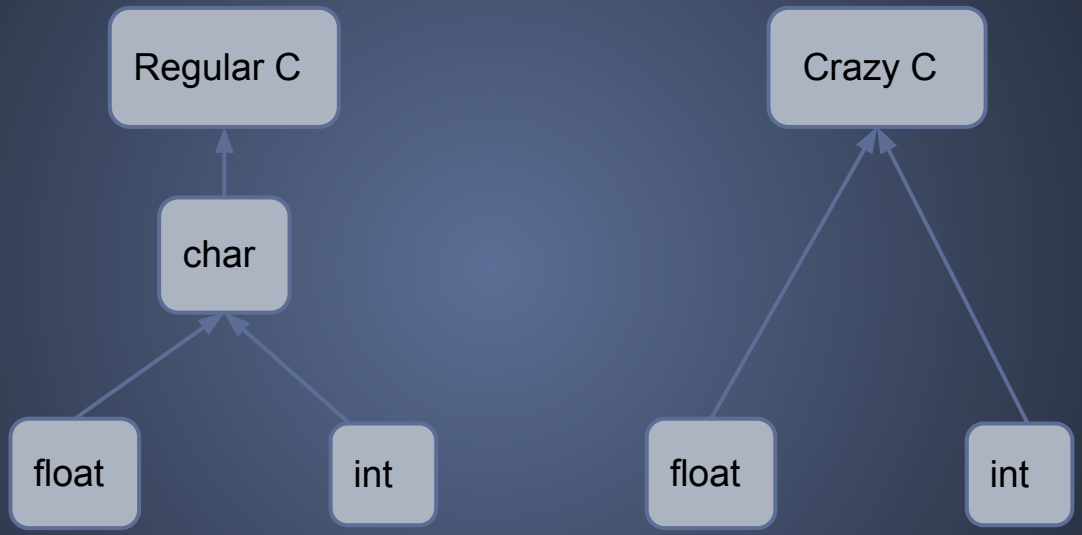
Memory has no types.

Separate mechanism from policy.

Use chaining to be conservative about punning.

Support cross-language inlining.

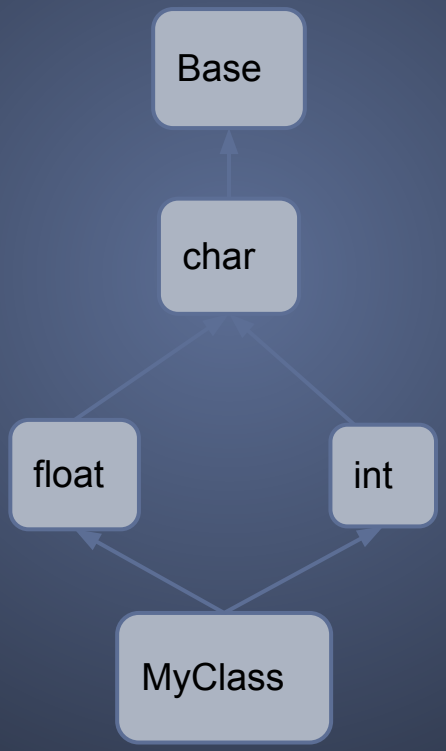
A Type Tree



Ancestors, Roots

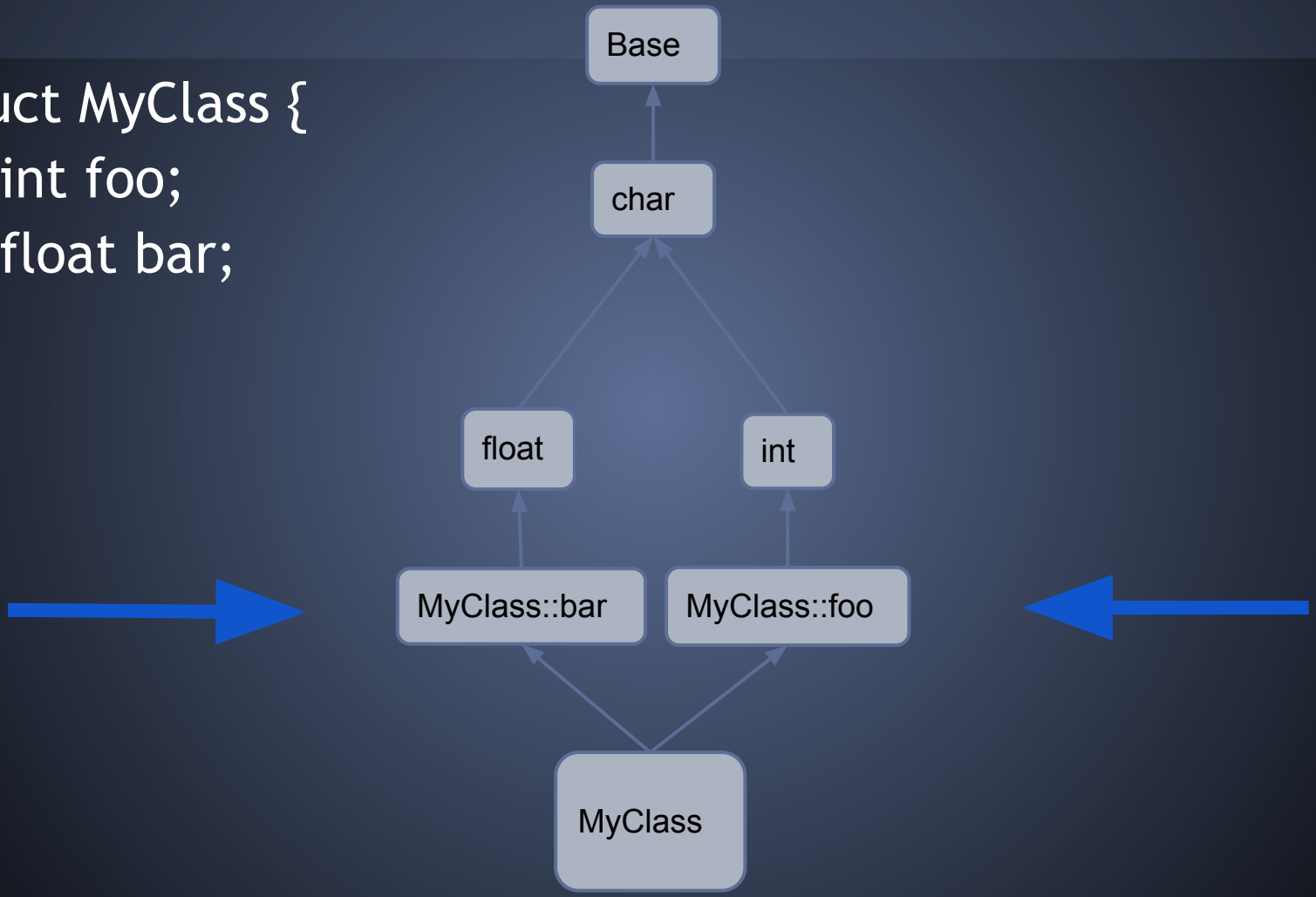
A Type DAG?

```
struct MyClass {
    int foo;
    float bar;
};
```



How about a more precise DAG...

```
struct MyClass {
    int foo;
    float bar;
};
```



Alternatives

Type DAG?
Instructions get multiple tags?
A separate datastructure for aggregates?

Type punning

```
int x;
*(float *)&x = 2.3f;
x = 4;
```

TBAA says NoAlias

BasicAA says MustAlias

Questions?