Towards Interfaces for Chapel

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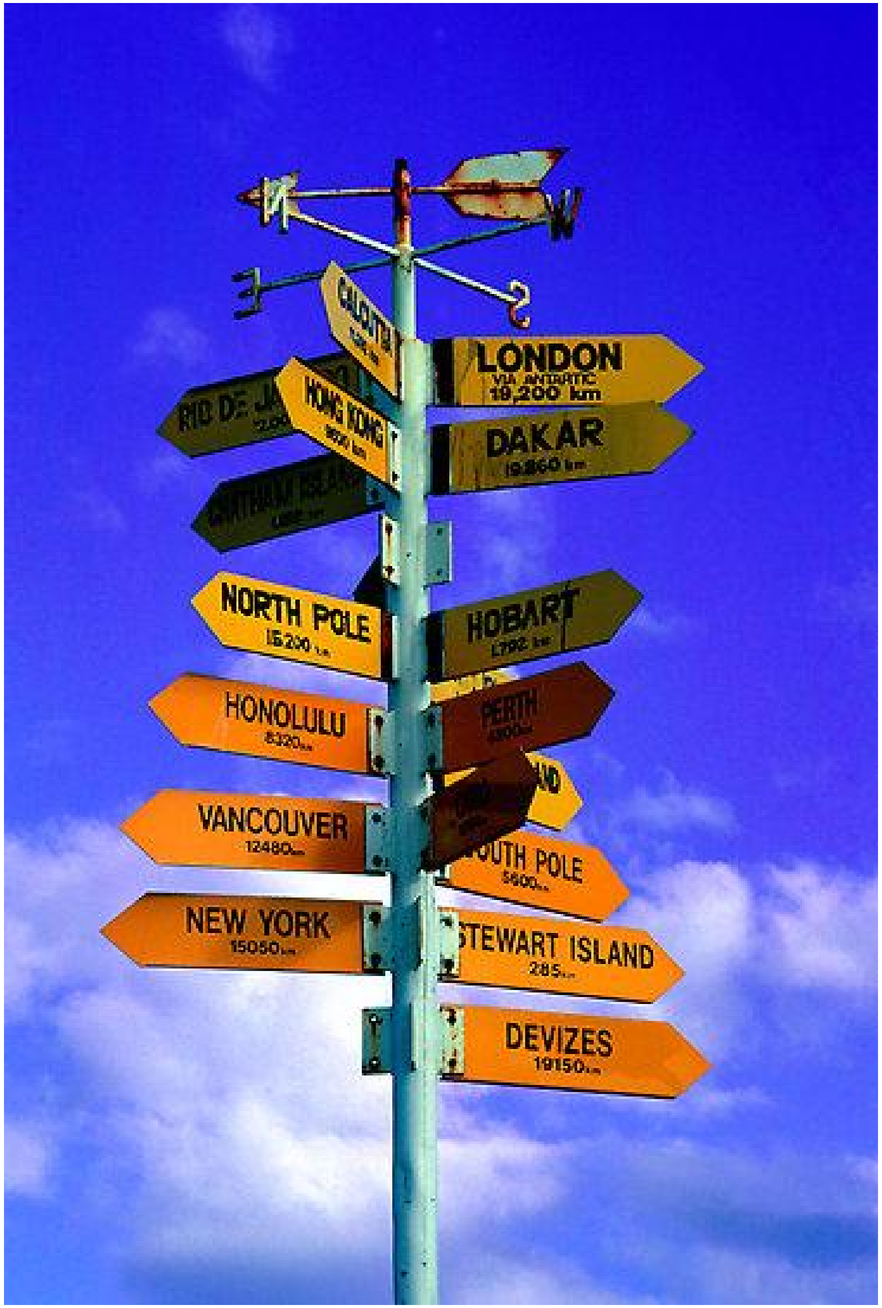
Why interfaces

How interfaces

Semantic changes

Compiler changes

Improving the compiler



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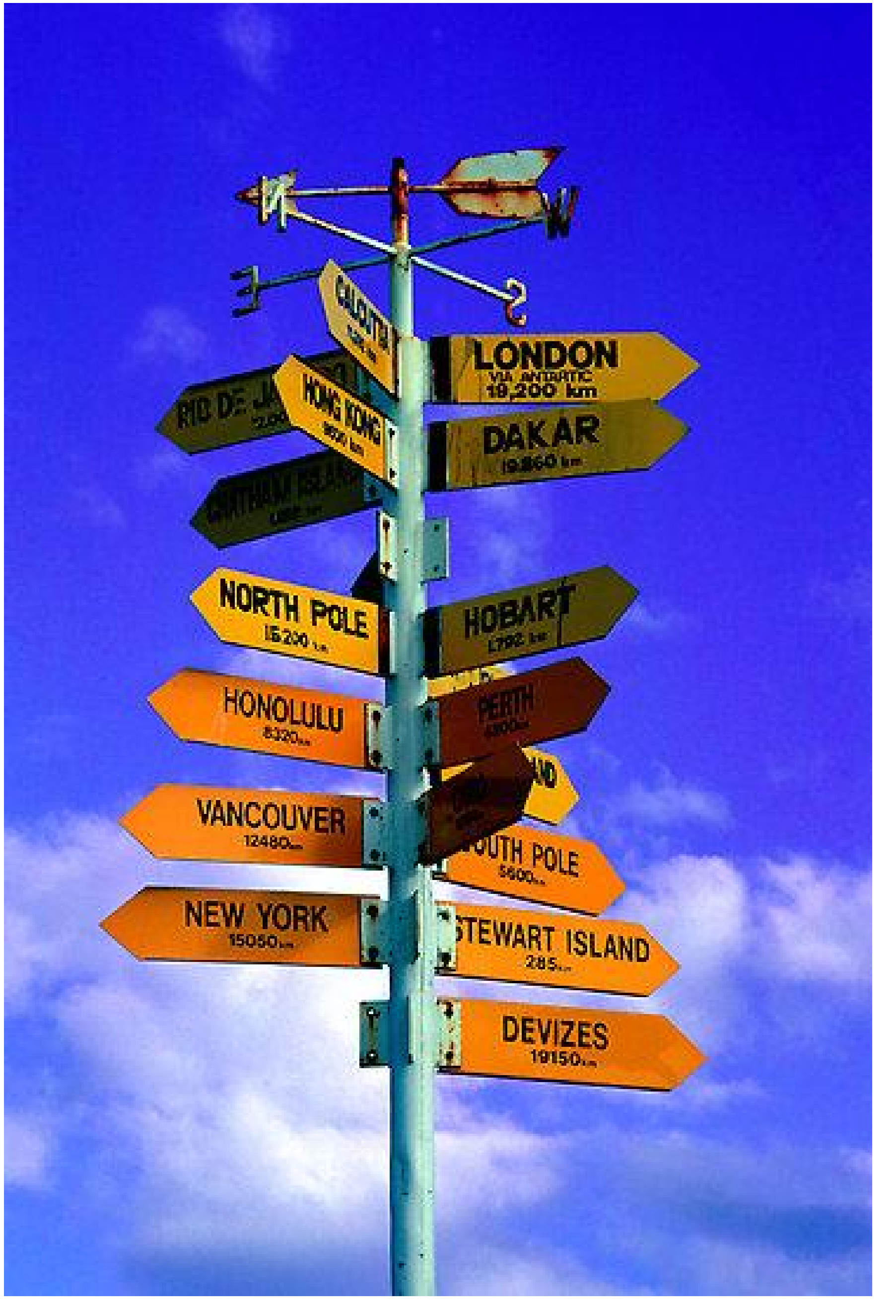


Error messages are improved

```
use Sort;
class C { }
var A : [1..10] C;
QuickSort(A);
```

```
/modules/standard/Sort.chpl:58: In function 'InsertionSort':
/modules/standard/Sort.chpl:64: error: unresolved call '<(C, C)'
SortExample.chpl:4: Type 'C' does not implement the 'Comparable' interface
/modules/internal/ChapelBase.chpl:326: note: candidates are: <(a: string, b: string)
```

Constrained generics can be checked eagerly

```
proc InsertionSort(Data: [?Dom](?T))                                    {
     const lo = Dom.low;
     for i in Dom {
          const ithVal : T = Data(i);
          var inserted     = false;
          for j in lo..i-1 by -1 {
               if (ithVal < Data(j)) {        error: unresolved call '<(T, T)'
                    Data(j+1) = Data(j);
               } else {
                    Data(j+1) = ithVal;
                    inserted  = true;
                    break;
               }
          }
          if (!inserted) { Data(lo) = ithVal; }
     }
}
```

Constrained generics can be checked eagerly

```
proc InsertionSort(Data: [?Dom](?T)) where implements LessThan(T) {
     const lo = Dom.low;
     for i in Dom {
          const ithVal : T = Data(i);
          var inserted     = false;
          for j in lo..i-1 by -1 {
               if (ithVal < Data(j)) {
                    Data(j+1) = Data(j);
               } else {
                    Data(j+1) = ithVal;
                    inserted  = true;
                    break;
               }
          }
          if (!inserted) { Data(lo) = ithVal; }
     }
}
```

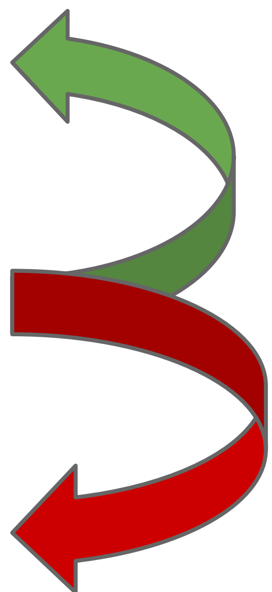
Resolves to function defined in LessThan interface

Function call hijacking is prevented

```
module M1 {
     proc helper() {
          writeln(“hello, world!”);
     }
     proc print_hello_world(x) {
          helper();
     }
}

proc helper() {
     writeln(“you’ve been hijacked!”);
}

proc main() {
     M1.print_hello_world(42);
}
```



you’ve been hijacked!

hello, world!

Compiler has less work to do

Unconstrained		Constrained	
`proc foo(x : T   )      { … }`		`proc foo(x : T   )      { … }`	✔
`proc foo(x : int)      { … }`	✔	`proc foo(x : int)      { … }`	
`proc foo(x : double)   { … }`	✔	`proc foo(x : double)   { … }`	
`proc foo(x : string)   { … }`	✔	`proc foo(x : string)   { … }`	
`proc foo(x : Car)      { … }`	✔	`proc foo(x : Car)      { … }`	
`proc foo(x : Account) { … }`	✔	`proc foo(x : Account) { … }`	

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Interfaces place requirements on types

```
interface Monoid(T) {
    proc binary_op(x:T, y:T):T;
    proc identity_element():T;
}

interface Comparable(T) {
    proc  <(x:T, y:T):bool;
    proc  >(x:T, y:T):bool;
    proc ==(x:T, y:T):bool;
}
```

Implements statements check a type against an interface's requirements

```
interface Monoid(T) {
    proc binary_op(x:T, y:T):T;
    proc identity_element():T;
}

proc binary_op(x:int, y:int):int { return x + y; }
proc identity_element():int      { return 0;     }

implements Monoid(int);
```

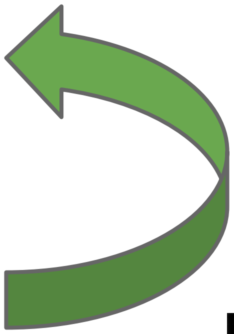
Interfaces allow us to resolve generics without instantiation

```
interface Loggable(T) {
    proc getID(T):int;
    proc getMessage(T):string;
}

interface Runnable(T) {
    proc run(T):bool;
}

proc runEvent(event : ?T) where
  implements Runnable(T) { … }

proc logEvent(id : int,
              message : string) { … }
```

```
proc processEvent(events : [](?T))
  where implements Loggable(T),
                   Runnable(T) {
  for i in 1..events.size {
    var event   : T      = events(i);
    var id      : int    = getID(event);
    var message : string = getMessage(event);

    if (runEvent(event)) {
      logEvent(id, message);
    }
  }
}
```

Eager resolution prevents function call hijacking

```
module M1 {
    proc helper() {
        writeln("hello, world!");
    }
    proc print_hello_world(x) {
        helper();
    }
}

proc helper() {
    writeln("you've been hijacked!");
}

proc main() {
    M1.print_hello_world(42);
}
```



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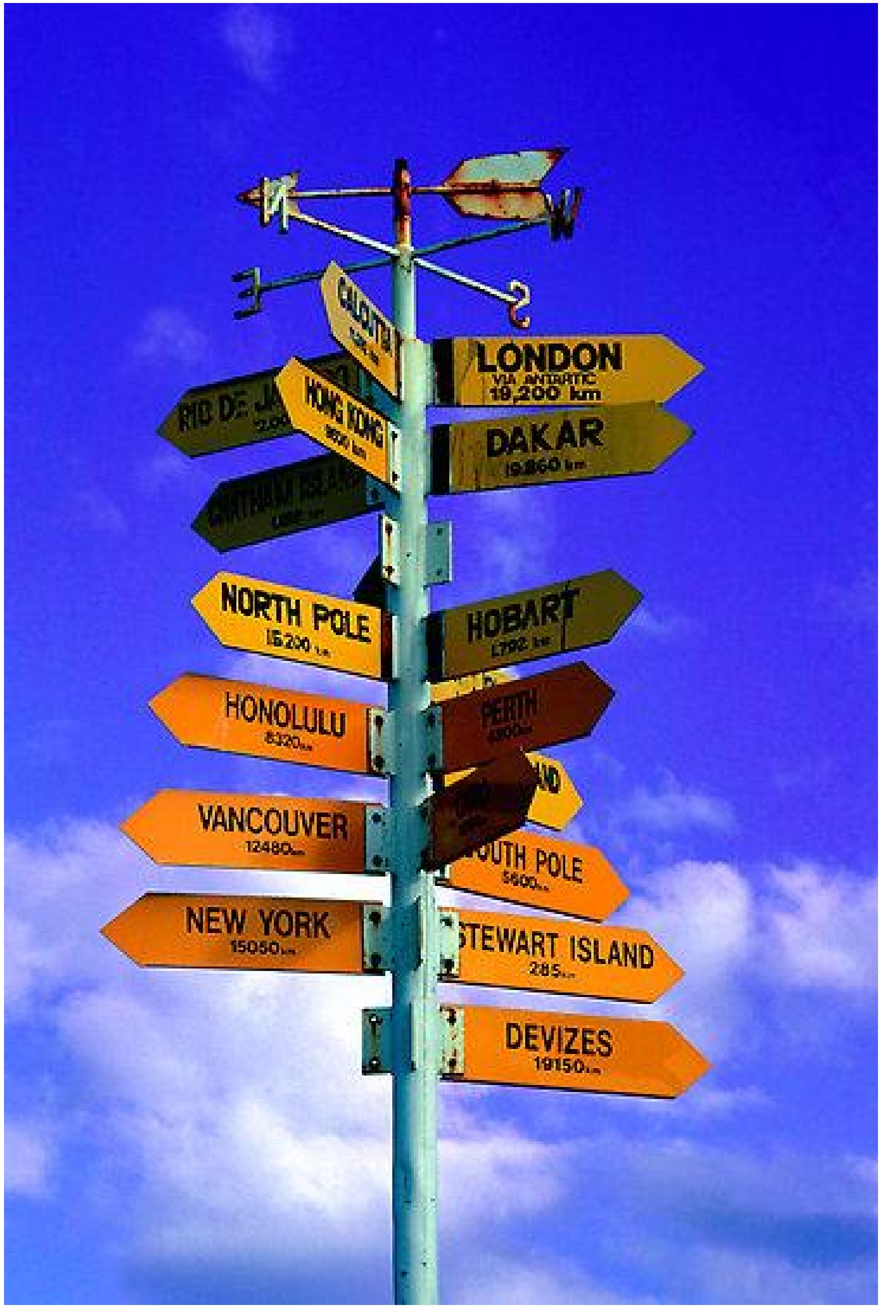

Constrained generics are prefered over unconstrained generics

```
proc logEvents(e:[](?T)) { … }
```

```
proc logEvents(e:[](?T)) where
  implements Loggable(T) { … }
```

```
logEvents(getEvents());
```

Constraints can’t increase

```
proc logEvents(l : Log, events : [](?U)) where
     implements Loggable(U); Runnable(U); Copyable(U);

proc processEvents(l : Log, events : [](?T)) where
     implements Loggable(T), Runnable(T) {

     for i in i..events.size {
          run(events(i));
     }

     logEvents(l, events);
}
```

Unconstrained generics gain the caller’s constraints

```
proc logEvents(l : Log, events : [](?U));where
     implements Loggable(U), Runnable(U);

proc processEvents(l : Log, events : [](?T)) where
     implements Loggable(T), Runnable(T) {

     for i in i..events.size {
          run(events(i));
     }

     logEvents(l, events);
}
```

Implementations are passed from one generic to the next

```
module A {
    interface Incrementable(T) {
        proc inc(x:T):T;
    }

    proc inc(x:int):int { return x + 100; }
    implements Incrementable(int);

    proc helper(x:?T)   where implements Incrementable(T) { return    inc(x); }
    proc incOuter(x:?T) where implements Incrementable(T) { return helper(x); }
}

proc inc(x:int):int { return x + 2; }
implements A.Incrementable(int);

A.incOuter(40);
```

⟶ **42**

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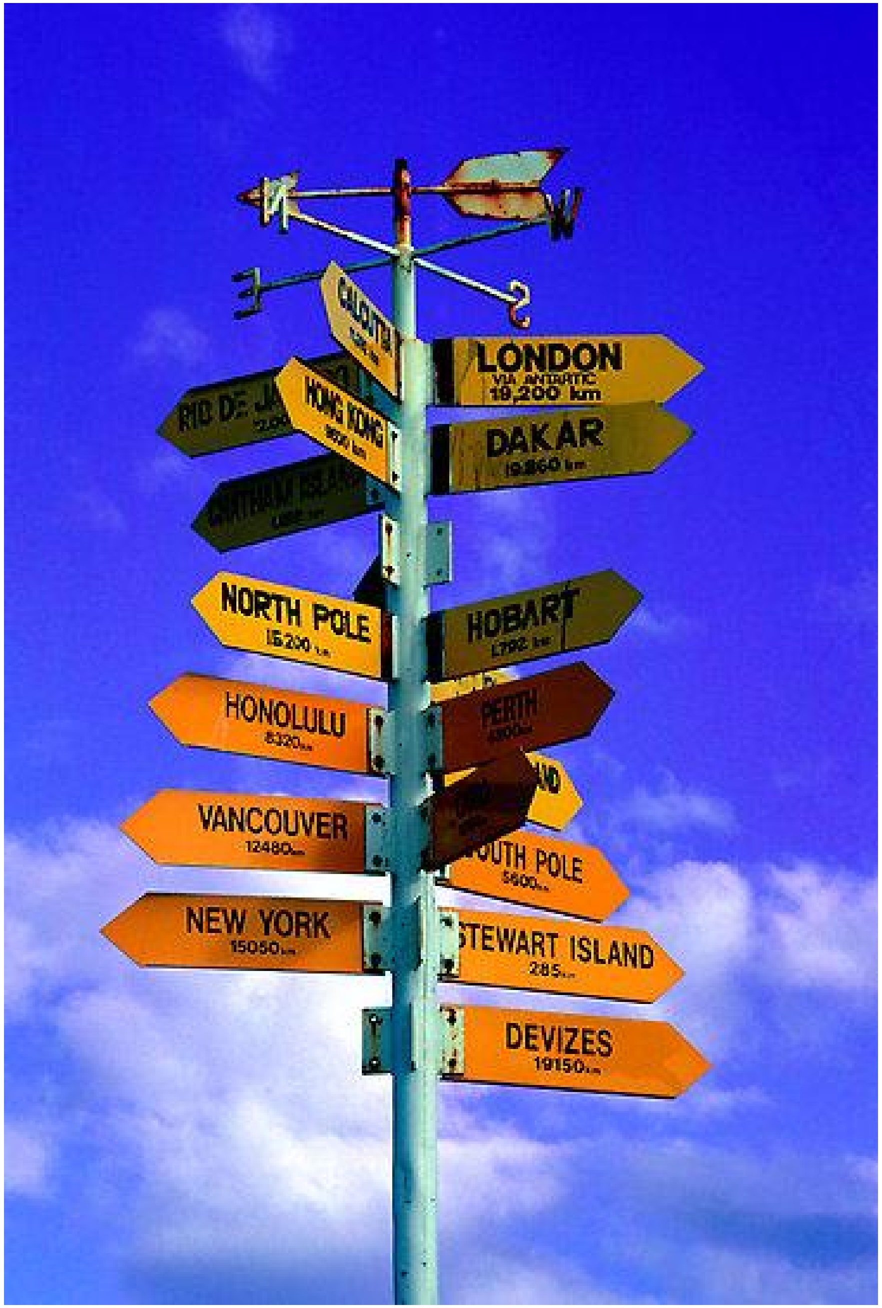

Implements statements cause implementations to be built

```
interface Foo(T) {
    proc foo(a:T):T;
    proc zap(a:T, b:T):bool;
}

proc foo(a:int):int { … }
proc zap(a:int, b:int):bool { … }

implements Foo(int);
        foo(int);
        zap(int, int);
```

```
implementation Foo(int) {
    [0]: 0x6542f0
    [1]: 0x6c3570
}
```

Calls can resolve to implementation slots

```
proc constrainedGeneric(x:T, y:U)
    where implements Foo(T), Bar(U) {

    foo(x);       [0][0]

    bar(y);       [1][0]

    zap(x, x);    [0][1]

    baf(y, 42);   [1][1]

    bar(x);       Unresolved call
}
```

```
interface Foo(T) {
    proc foo(a:T):T;
    proc zap(a:T, b:T):bool;
}

interface Bar(U) {
    proc bar(x:U):U;
    proc baf(x:U, y:int):int;
}
```

Specialization replaces implementation slots with pointers

```
proc constrainedGeneric(x: Int, y: Real)
     where implements Foo(T), Bar(U) {

     foo(x);        0x6542f0

     bar(y);        0x8281e0

     zap(x, x);     0x6c3570

     baf(y, 42);    0x6b8e20

}
```

```
implementation Foo(int) {
     [0]: 0x6542f0
     [1]: 0x6c3570
}

implementation Bar(real) {
     [0]: 0x8281e0
     [1]: 0x6b8e20
}

constrainedGeneric(42, 100.0);
```

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The Chapel compiler has room for improvement

- Large and complicated passes

Function Resolution:
6841 SLOC!

- Mixing of subtyping and tagging
- Poorly documented invariants spread across large sections of code
- Using common C++ idioms and STL classes would make life easier

Chapel mixes subtyping and tagging

```
isFnSymbol(node)

fnSymbol->hasFlag(FLAG_GENERIC)

aggregateType->aggregateTag == AGGRAGATE_CLASS
```

More subtyping would result in less memory usage

```
FnSymbol*  instantiatedFrom;
SymbolMap  substitutions;
BlockStmt* instantiationPoint;
SymbolMap  partialCopyMap;
FnSymbol*  partialCopySource;
Symbol*    retSymbol;
int        numPreTupleFormals;
```

Invariants are not well documented

- Copying a node does not result in a well-formed AST
- remove_help doesn't adjust a node's list member

```
breakInvariant();

intermediateCall();
call();

breakAndFixInvariant();
intermediateCall();

call();
intermediateCall();

fixInvariant();
```

Invariant tracking is time consuming and difficult

```
if (newType) {
  map.put(fn->retType->symbol, newType->symbol);
}

FnSymbol* newFn = fn->partialCopy(&map);
fn->finalizeCopy();

addCache(genericsCache, root, newFn, &all_subs);

if (call) {
  newFn->instantiationPoint = getVisibilityBlock(call);
}

Expr* putBefore = fn->defPoint;
if( !putBefore->list ) {
  putBefore = call->parentSymbol->defPoint;
}

putBefore->insertBefore(new DefExpr(newFn));

for (int i = 0; i < subs.n; i++) {
  if (ArgSymbol* arg = toArgSymbol(subs.v[i].key)) {
    if (arg->intent == INTENT_PARAM) {
      Symbol* key = map.get(arg);
      Symbol* val = subs.v[i].value;
      if (!key || !val || isTypeSymbol(val))
        INT_FATAL("error building parameter map in instantiation");
      paramMap.put(key, val);
    }
  }
}

for_formals(arg, fn) {
  if (paramMap.get(arg)) {
    Symbol* key = map.get(arg);
    Symbol* val = paramMap.get(arg);
    if (!key || !val)
      INT_FATAL("error building parameter map in instantiation");
    paramMap.put(key, val);
  }
}
```

Using common C++ idioms and STL classes makes life easier

- Copy constructors
- operator[]
- Iterators
- vector, map, and list
- Methods over functions

Towards interfaces for Chapel

- Improved programmer experience
- New behaviours for constrained generics
- Function resolution in the presence of type variables
- Suggested improvement to the compiler
- Questions?