Visibility Control:
Use and Import Statement Improvements

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Outline

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Introduction
Introduction

• The Chapel team at Cray/HPE is working towards Chapel 2.0
  • This means determining which language features are likely to be stable

• ‘use’ statements have been part of the language for a long time
  • Enable symbols in one module to be visible in another module
    • Either with *unqualified* access (no module prefix)…
      … or *qualified* access (with the module prefix)

```
use M;
writeln(x); // prints the value of M.x
writeln(M.y); // prints the value of M.y
```
Introduction

- Chapel 1.12 / 1.13 improved support for privacy and namespace control, e.g.
  - Added ‘public’ and ‘private’ designators for symbols
  - Added ‘only’ and ‘except’ clauses to ‘use’ statements
    - These limit the symbols brought in for unqualified access
  - These changes were presented at CHUIW 2016

- But we also had several extensions and changes planned that weren’t done
  - Some of these changes would break backwards compatibility

- This talk will cover recent changes, as well as some forward-looking features
Transitivity
Transitivitiy

To motivate some of these changes to ‘use’, we need to talk about transitivity.

Prior to Chapel 1.20, ‘use’ statements were always ‘public’.

This meant that symbols brought in were made more broadly available.

```
module B { use A; ... }
module C {
 ...
    proc bar() {
        use B;
        writeln(x); // ‘x’ is defined by module ‘A’, but ‘C’ didn’t ‘use A’ itself
    }
}
```
Transitivity

• This was a problem
  • Required increased care when naming symbols…

```java
module B { use A; ... }
module C {
  var x = 3;
  proc bar() {
    use B;
    writeln(x); // 'x' is defined by module 'A', so this won't necessarily print 3!
  }
}
```
Transitivity

• This was a problem
  • Could lead to hijacking if a library you rely on changed its underlying definition
    • Or what modules it relied upon…
    • Or even if modules it relied upon changed!

• Could also lead to compilation errors when the symbols would conflict

• Meant that users might rely on implementation details
  • Good language design should give library writers control over what is seen
Transitivity

• Could work around this by limiting the scope of the ‘use’ statement
  • E.g. by putting the ‘use’ inside a function body:

```csharp
module B {
    proc foo() {
        use A;
    }
}
```

• But this wasn’t always feasible
  • If module is integral to your program, will dramatically increase # of ‘use’s
  • If you need the module due to an argument type, you are out of luck
Transitivity

• We added ‘public’ and ‘private’ specifiers to ‘use’ statements
  
  ```
  private use A;
  ```

• This allows library writers to intentionally choose which ‘use’s are visible
• We also switched the default to ‘private’
  • This could result in some broken code, but the fixes should be simple
  • And default code will be safer going forward
Transitivity: Impact on Libraries

• All default ‘use’ statements in the standard and package libraries are now ‘private’
• All default ‘use’ statements in the internal libraries are still ‘public’
  • Want to make some of these ‘private’, too, but it’s not trivial
• Many ‘use’ statements are now either explicitly ‘public’ or ‘private’

Library Use Statements

- Explicitly Private: 38%
- Explicitly Public: 6%
- Default (private): 23%
- Default (public): 33%
Transitivity: Impact on Libraries

• As a result, some modules are no longer available by default to user programs
  • RangeChunk, SysCTypes, CommDiagnostics now require an explicit ‘use’
  • Some of these were accidentally included before (e.g. CommDiagnostics)
  • Others we knew had been getting included, but didn’t want to still do so

• These modules were not used in the common case
  • So not including them by default makes sense
Transitivity: Impact on Libraries

• And default-included symbols no longer take precedence over outer-scoped
  • Here’s an example of when that was a problem:

```javascript
var e = 17;
{
    use Mod;
    // Used to print Math.e because of the default ‘public use’ of Math by Mod
    // Now, the default ‘use’ is ‘private’, so it prints ‘17’
    writeln(e);
}
```
Transitivity

• Transitive ‘use’ statements are powerful, but often have broad consequences

• Giving users control over the transitivity of their ‘use’ statements is valuable
  • Users have better knowledge of what is appropriate for their code

• Changing the default transitivity makes code safer
  • Users must actively choose to make a ‘use’ transitive
  • Therefore, they are more likely to understand what doing so means

• And limiting the transitivity of library ‘use’s improves the user experience
  • It reduces the potential for namespace confusion
Correctness and Compilation Speed
Or:
Why Is My Compilation Slower? An Apology
Correctness and Compilation Speed

• Function resolution in the compiler had an “optimization”, standardModuleSet
  • Had been in the compiler since the Dawn of Time*
  • Basically, treated every module used by default as though it was in one scope
  • This made it easy to resolve default symbols
    • Too easy…

*The compiler has not been around since the Dawn of Time
Correctness and Compilation Speed

• This “optimization” assumed everything was visible everywhere
  • As a result, some internal modules were accessing modules they didn’t use
    • And that weren’t transitively available to them, either:

```
module ChapelBase {
    // needed ‘private use ChapelEnv;’ to access ‘CHPL_NETWORK_ATOMICS’
    ...
    config param useAtomicTaskCnt =
        CHPL_NETWORK_ATOMICS != "none";
}
```

• There were many other examples of bad behavior enabled by it
Correctness and Compilation Speed

• There wasn’t a way to reconcile this “optimization” and ‘private’ at all
  • ‘private’ depends on the module hierarchy being maintained
    • Both for ‘private use’ and ‘private’ symbols
      • standardModuleSet removes that hierarchy entirely
  • It enabled a lot of bugs
  • And made the internal modules harder to maintain as a result
Correctness and Compilation Speed

- So we removed the standardModuleSet …

… resulting in an average slowdown of 26.7% for our testing suite as a whole … … and roughly 37% for arkouda!
Correctness and Compilation Speed

- Still, removing the “optimization” was the right thing to do
- So we set about looking at ways to mitigate this impact
  - Mostly by improving parts of function resolution

![Average Compilation Time Per Pass: resolve](image)

- 22.4% improvement from simplifying visible function determination
- 5.1% improvement from reducing number of times a scope’s visibility is checked
Correctness and Compilation Speed

• Ultimately, compilation is still slower than it was
  • But most of the impact from this change has been recovered

  • We’re hoping to work more on compilation in this release cycle

• The default libraries are more accurate and less tangled than they were before
  • Though work still needs to be done to disentangle them further
Renaming
Renaming

• ‘use’ statements can limit the symbols brought in to ‘only’ specific symbols
  
  ```
  use Mod only veryLongName;
  ```

• When ‘only’ lists were added, they also enabled symbol renaming
  
  ```
  use Mod only veryLongName as vln;
  writeln(vln);  // Prints value of ‘Mod.veryLongName’
  ```

• This allowed users to avoid:
  • conflicts with symbols brought in from other modules,
  • shadowing symbols at outer scopes that share the same name,
  • and having to type long descriptive names repeatedly.
Renaming

• As a side effect, we could rename submodules when using their parent module
  
  \[
  \texttt{use Mod only InnerMod as IM;}
  \]
  
• We decided to extend this to enable renaming when the module itself is used…
  
  \[
  \texttt{use Mod.InnerMod as IM;}
  \]
  
… which allowed top-level modules to be renamed for the first time
  
  \[
  \texttt{use Mod as M;}
  \]
Qualified Access and ‘import’
Import Statements

• ‘use’ statements have been imprecise
  • Default behavior brought every visible symbol into scope
    • However, could limit the symbols brought in with ‘except’ and ‘only’ lists
  • Design focused on “programming in the small” scenarios

• Users desired a feature for more precise access of module symbols
  • One better suited for maintaining large-scale software
  • Ideally, without breaking current code
We designed and implemented the ‘import’ statement as an alternative to ‘use’

- Simplest form enables qualified access to the symbols in a module:

```
import MyModule;
writeln(MyModule.sym1);  // Enabled by the ‘import’
writeln(sym1);           // Not enabled, won’t work
```

- This was previously only achievable with “empty” ‘use’ statements, e.g.

```
use MyModule only;
use MyModule except *;
```
Import Statements: Accessing Module Contents

• Can also enable unqualified access to a single symbol within a module:

```plaintext
import MyModule.sym1;
writeln(sym1); // Enabled by the ‘import’
writeln(MyModule.sym1); // Not enabled by the ‘import’
```

• Or multiple symbols within a module:

```plaintext
import MyModule.{sym1, sym2, sym3};
```

• Neither of these options was available previously
  • ‘use’ statements always enabled qualified access in addition to unqualified
Import Statements: Impact on Libraries

• We replaced all “empty” ‘use’ statements in the libraries with ‘import’ statements
• And are starting to use other variants, too

Library Use and Import Statements

- 87% use statements
- 13% import statements

Library Import Statements

- 71% qualified access
- 29% unqualified access
Import Statements: Renaming

• Modules that are imported can be renamed:

```plaintext
import MyModule as Foo;
writeln(Foo.sym1);       // Enabled by the ‘import’
writeln(sym1);           // Not enabled by the ‘import’
writeln(MyModule.sym1);  // Not enabled by the ‘import’
```

• As can symbols that are imported for unqualified access:

```plaintext
import MyModule.sym1 as x;  // or:
import MyModule.{sym1 as x, sym2 as y};
```
Import Statements: Nested Modules

• Nested modules must be named using their parent modules...

```plaintext
module OuterMod {
    import InnerMod; // error: looks for top-level module ‘InnerMod’
    import OuterMod.InnerMod; // OK: names module starting from top-level
    writeln(InnerMod1.sym1);
    module InnerMod { var sym1 = ...; }
}
```

• Unlike ‘use’ statements, ‘import’ statements can’t use relative naming
  • E.g. ‘OuterMod’ can’t just write ‘import InnerMod;’
Import Statements: Nested Modules

• Nested modules can be named directly in certain circumstances:
  • E.g. after being made available by another ‘import’ or ‘use’
    
    ```
    use OuterMod;  // makes ‘OuterMod’s symbols available
    import InnerMod;  // ‘InnerMod’ visible due to ‘use OuterMod’
    ```

• Both ‘use’ and ‘import’ can shorten the path with ‘this’ if within a parent module…

  ```
  module OuterMod {
    module InnerMod { … }
    import this.InnerMod;  // Enabled by being within ‘OuterMod’
  }
  ```
Import Statements: Nested Modules

• Nested modules can also be imported using ‘super’ if within a sibling module
  • Like ‘this’, ‘super’ also works for ‘use’ statements

    module OuterMod {
        module InnerMod { ... }
        module SiblingMod {
            // Enabled by being within OuterMod.SiblingMod
            import super.InnerMod;
        }
    }
Import Statements: Nested Modules

• Using ‘this’/‘super’ makes ‘use’ and ‘import’ safer than using relative names
  • Origin of relatively used modules is much more obvious to the reader

• This style of ‘use’ makes code more robust to later changes
  • If dependency defines another module with same name, won’t conflict
Import Statements: Public / Private

• ‘import’ statements can be declared ‘public’ or ‘private’
  • Default is ‘private’
    • as with ‘use’, reduces unintentional leaking of names
  • ‘public’ means symbols brought in are *re-exported*

```javascript
module Mod {
    public import OtherMod;
}
module ThirdMod {
    import Mod.OtherMod;  // ‘OtherMod’ acts like a submodule of ‘Mod’
}
```
Import Statements: Impact

• The ‘import’ statement supports module access in a more precise manner
  • Its default behavior minimally extends the scope

• It also enables new functionality:
  • Can re-export symbols
  • Can bring symbols in for unqualified access without enabling qualified access
What’s Next?
What’s Next?

• Extend ‘import’ to support multiple expressions in a single statement
  
  ```
  import Mod1.{a, b}, Mod2.{x, y};    // Should this be allowed?
  ```
  
  • See issue #14971 and #15583

• Enable re-exporting for ‘use’ statements
  
  • See issue #15282

• Implement ability to ‘use’ module and disable qualified access (issue #15457)
  
  ```
  use Mod as _;
  writeln(Mod.x);    // Wouldn’t work, not enabled by this ‘use’
  writeln(x);        // Would still work, enabled by this ‘use’
  ```
What’s Next?

• Design story for ‘private’ fields/methods and types
  • See issue #6067

• Continue reviewing the set of symbols made available by default

• Continue improving ‘use’ statements within internal modules
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