The Use and I: Transitivity of Module Uses and its Impact

Lydia Duncan, Cray Inc.
CHIUW 2016
May 27th, 2016
Safe Harbor Statement

This presentation may contain forward-looking statements that are based on our current expectations. Forward looking statements may include statements about our financial guidance and expected operating results, our opportunities and future potential, our product development and new product introduction plans, our ability to expand and penetrate our addressable markets and other statements that are not historical facts. These statements are only predictions and actual results may materially vary from those projected. Please refer to Cray's documents filed with the SEC from time to time concerning factors that could affect the Company and these forward-looking statements.
Symbols visible to B via a ‘use’ also visible:
- within C’s main
- other uses of B

```plaintext
module A {
    var bar = 13;
    proc foo() { ... }
}

module B {
    use A;
    var baz = 19;
    proc flip(x: int) { ... }
}

module C {
    var flop = 7;
    proc main() {
        use B;
        flip(bar);
    }
}
```
The Use and I: Transitive Uses

- Symbols visible to B via a ‘use’ also visible to uses of B
  - Best represented as a tree of ‘use’

```
use D, E;
use F, G;
use B, C;
```

![Diagram showing the transitive uses of symbols]

Symbols visible to B via a ‘use’ also visible to uses of B Best represented as a tree of ‘use’
The Use and I: Transitive Uses

- **Symbols visible to B via a ‘use’ also visible to uses of B**
  - Best represented as a tree of ‘use’s
  - Each path in tree is a “use chain” (e.g. A->B->D, A->C->F)
Symbols now visible to B also visible:
- within C’s main
- other uses of B

```plaintext
module B {
  use A;

  var baz = 19;
  proc flip(x: int) { ... }
}
```

```plaintext
module A {
  var bar = 13;
  proc foo() { ... }
}
```

```plaintext
module C {
  var flop = 7;
  proc main() {
    use B;
    flip(bar);
  }
}
```
The Use and I: Transitive Uses

- Symbols visible to B via a ‘use’ also visible to uses of B
  - Can avoid extra work

```plaintext
module A {
    class foo { ... }
}

module B {
    use A;

    proc foo.bar() { ... }
}

module C {
    proc main() {
        use B; // Instead of use A, B;

        var baz = new foo();
        // foo visible because B uses A
        baz.bar();
    }
}
```
The Use and I: Transitive Uses

- Symbols visible to B via a ‘use’ also visible to uses of B
  - Can avoid extra work
  - But can lead to unexpected issues
    - C’s writer might not notice use of A

```plaintext
module A {
    var bar = 13;
    proc foo() { ... }
}

module B {
    use A;

    var baz = 19;
    proc flip(x: int) { ... }
}

module C {
    var bar = 7;

    proc main() {
        use B;

        flip(bar); // Finds A.bar, not C.bar
    }
}
```
The Use and I: Transitive Uses

- **Symbols visible to B via a ‘use’ also visible to uses of B**
  - Can avoid extra work
  - But can lead to unexpected issues
  - Same issues can occur with just B

```plaintext
module B {
  var bar = 19;
  proc flip(x: int) { ... }
}

module C {
  var bar = 7;

  proc main() {
    use B;

    flip(bar); // Finds B.bar, not C.bar
  }
}
```
The Use and I: Import Control

● Chapel 1.13 adds import control for use statements
  ● ‘except’ keyword prevents unqualified access to symbols in list
    ```
    use B except bar;  // All of B’s symbols other than bar can be named directly
    ```
  ● ‘only’ keyword limits unqualified access to symbols in list
    ```
    use B only flip;  // Only B’s flip can be named directly
    ```
  ● Permits user to avoid importing unnecessary symbols
    ● Including symbols which cause conflicts

```module B {
  var bar = 19;
  proc flip(x: int) { ... }
}
```

● Can rename imported symbols
  ```
  use B only bar as baz;
  // Can reference B.bar via baz
  ```

```module C {
  var bar = 7;

  proc main() {
    use B except bar;

    flip(bar); // Finds C.bar, not B.bar
  }
}```
The Use and I: Import Control

- Import control must affect all uses in use chain
  - Would be equally incorrect to find A’s bar or B’s bar.

```plaintext
module A {
  var bar = 13;
  proc foo() { ... }
}

module B {
  use A;

  var bar = 19;
  proc flip(x: int) { ... }
}

module C {
  var bar = 7;

  proc main() {
    use B except bar;

    flip(bar); // Finds C.bar
  }
}
```
The Use and I: Import Control

- Nested import control must be considered
  - Shouldn’t find symbols excluded by deeper import control

```plaintext
module A {
  var bar = 13;
  proc foo() { ... }
}

module B {
  use A only foo;

  var goop = 19;
  proc flip(x: int) { ... }
}

module C {
  var bar = 7;

  proc main() {
    use B except goop;

    flip(bar); // Finds C.bar
  }
}
The Use and I: Renaming

- Renaming a symbol should not allow access to old name

```plaintext
module A {
    var bar = 13;
    proc foo() { … }
}

module B {
    use A;
    var bar = 19;
    proc flip(x: int) { … }
}

module C {
    var bar = 7;
    proc main() {
        use B only bar as baz;
        flip(bar); // Finds C.bar
    }
}
```
The Use and I: Renaming

- Renaming a symbol should not allow access to old name
  - And nested renaming should not break this condition

```plaintext
module A {
  var bar = 13;
  proc foo() { ... }
}

module B {
  use A only bar as baz;
  var goop = 19;
  proc flip(x: int) { ... }
}

module C {
  var bar = 7;
  proc main() {
    use B only baz as biff;
    flip(bar); // Finds C.bar
  }
}
```
Compiler Implementation
The Use and I: Transitive Uses

- **Symbols visible to B via a ‘use’ also visible to uses of B**
  - Best represented as a tree of ‘use’s
  - Each path in tree is a “use chain” (e.g. A->B->D, A->C->F)

```
use B, C;
use D, E;
use F, G;

A → B → D, E, F, G
```
The Use and I: Scope Resolve

● **Scope resolution**
  ● Handles variable, module name resolution
  ● Traverses in breadth-first order
  ● ‘Use’ tree built once per scope after module names resolved
    ● Traversed many times

```
use B, C;
use D, E;
use F, G;
```

Traversal order:
- A
- <gap>
- B
- C
- <gap>
- D
- E
- F
- G
- ...

Implementation ignored these connections
With ‘except’ and ‘only’ keyword, ‘use’ chains matter more

- Earlier limits should affect search of later modules in chain
- Need to apply these limits when creating ‘use’ tree

```
use B except foo;
use D;
use ...
```
The Use and I: Scope Resolve

- With ‘except’ and ‘only’ keyword, ‘use’ chains matter more
  - Earlier limits should affect search of later modules in chain
  - Need to apply these limits when creating ‘use’ tree

```
use B except foo;
use D except foo;

A
B
...
D
```

Note: In the case where B is ‘use’d in multiple ‘use’ chains, these modifications should not be visible outside of the ‘use’ from A
With ‘except’ and ‘only’ keyword, ‘use’ chains matter more

- Earlier limits should affect search of later modules in chain
- Need to apply these limits when creating ‘use’ tree
  - This can get tricky when multiple limits are present
With ‘except’ and ‘only’ keyword, ‘use’ chains matter more

- Earlier limits should affect search of later modules in chain
- Need to apply these limits when creating ‘use’ tree
  - This can get tricky when multiple limits are present

```
use B except foo;

use D except bar, foo;
```

```
A

B

D
```

...
Function resolution
- Handles functions, some field resolution
  - Chooses best match from all matches at all visible scopes
- Traverses ‘use’\textquotesingle s depth-first
- Later ‘use’\textquotesingle s in chain accessed through earlier ‘use’\textquotesingle s

Traversal order:
- A
- B
- D
- E
- C
- F
- G
- ...

use B, C;

use D, E;

use F, G;

A

B

C

D

E

F

G
The Use and I: Function Resolution

- Can determine whether to follow a ‘use’ chain
  - If ‘except’ or ‘only’ list precludes desired name, skip that branch
  - Single check saves compilation time

```plaintext
use B only bar;
use C;

A
use D, E;
B
use F, G;
C
D
E
F
G
```

Traversal order:
- A
- B
- D
- E
- C
- F
- G
- ...

...
The Use and I: Conclusions

- **Control over ‘use’ transitivity should be in user’s hands**
  - Module designer has best knowledge of symbols to expose/hide
  - Intend to provide via reuse of ‘public’/‘private’ keywords
    ```cpp
    private use M;
    public use N;
    ```

- **Starting from “transitive by default” was beneficial**
  - Design of features forced to account for transitivity immediately
  - Found tricky cases early

- **Still deciding on default behavior**
Legal Disclaimer

Information in this document is provided in connection with Cray Inc. products. No license, express or implied, to any intellectual property rights is granted by this document.

Cray Inc. may make changes to specifications and product descriptions at any time, without notice.

All products, dates and figures specified are preliminary based on current expectations, and are subject to change without notice.

Cray hardware and software products may contain design defects or errors known as errata, which may cause the product to deviate from published specifications. Current characterized errata are available on request.

Cray uses codenames internally to identify products that are in development and not yet publically announced for release. Customers and other third parties are not authorized by Cray Inc. to use codenames in advertising, promotion or marketing and any use of Cray Inc. internal codenames is at the sole risk of the user.

Performance tests and ratings are measured using specific systems and/or components and reflect the approximate performance of Cray Inc. products as measured by those tests. Any difference in system hardware or software design or configuration may affect actual performance.

The following are trademarks of Cray Inc. and are registered in the United States and other countries: CRAY and design, SONEXION, and URIKA. The following are trademarks of Cray Inc.: ACE, APPRENTICE2, CHAPEL, CLUSTER CONNECT, CRAYPAT, CRAYPORT, ECOPHLEX, LIBSCI, NODEKARE, THREADSTORM. The following system family marks, and associated model number marks, are trademarks of Cray Inc.: CS, CX, XC, XE, XK, XMT, and XT. The registered trademark LINUX is used pursuant to a sublicense from LMI, the exclusive licensee of Linus Torvalds, owner of the mark on a worldwide basis. Other trademarks used in this document are the property of their respective owners.
Declaring symbol “private” impacts outside access

- No explicit naming allowed from outer scope
- ‘Use’ will not allow unqualified access of symbol either
- Still visible from scopes nested within defining scope

```plaintext
private var foo = ...
proc bar() { ... } // Can reference foo within bar, etc.
```

Implementation:

- Same check on symbol match visibility used in both passes
  - Scope resolve looks at further ‘use’ depth if only private symbols found
  - Function resolution merely avoids that match
With ‘except’ and ‘only’ keyword, ‘use’ chains matter more

- Earlier limits should affect search of later modules in chain
- Need to apply these limits when creating ‘use’ tree
  - This can get tricky when multiple limits are present
With ‘except’ and ‘only’ keyword, ‘use’ chains matter more

- Earlier limits should affect search of later modules in chain
- Need to apply these limits when creating ‘use’ tree
  - This can get tricky when multiple limits are present

```
use B except foo;
use D only bar;
...
```

If an outer ‘except’ list is distinct from an inner ‘only’ list, the ‘only’ list will be unchanged.
With ‘except’ and ‘only’ keyword, ‘use’ chains matter more
- Earlier limits should affect search of later modules in chain
- Need to apply these limits when creating ‘use’ tree
  - This can get tricky when multiple limits are present
The Use and I: Scope Resolve

- With ‘except’ and ‘only’ keyword, ‘use’ chains matter more
  - Earlier limits should affect search of later modules in chain
  - Need to apply these limits when creating ‘use’ tree
    - This can get tricky when multiple limits are present

- \textbf{example:}
  
  ```
  use B only foo;
  use D only foo;
  
  A
  \textit{B}
  \textit{...}
  \textit{D}
  ```

- If an outer ‘only’ list is distinct from an inner ‘except’ list, the ‘only’ list will replace the ‘except’ list.
The Use and I: Scope Resolve

- With ‘except’ and ‘only’ keyword, ‘use’ chains matter more
  - Earlier limits should affect search of later modules in chain
  - Need to apply these limits when creating ‘use’ tree
    - This can get tricky when multiple limits are present

```perl
use B only foo;
use D only bar;
...
```

```
A

B
```

```
D
```

```
...
With ‘except’ and ‘only’ keyword, ‘use’ chains matter more
- Earlier limits should affect search of later modules in chain
- Need to apply these limits when creating ‘use’ tree
  - This can get tricky when multiple limits are present

```
use B only foo;
use D only;
...
```

If an outer ‘only’ list is distinct from an inner ‘only’ list, it will be as if that ‘use’ does not occur.

And any overlap will be handled appropriately.