Matriona: Class Nesting with Parameterization in Squeak/Smalltalk

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March 16, 2016

Overview

Introduction

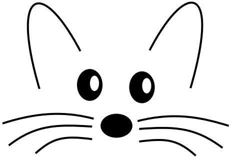
Requirements

Mechanism

Examples

Conclusion

Vision for Matriona



Matriona should be a module system . . .

- . . . **for Squeak/Smalltalk**
  - Easy to implement (metaprogramming, reflection)
  - Needs a module system
- . . . for *long-living* systems (c.f. highly available systems)
  Cannot turn off (restart) system to install new software
- . . . for a programming environment that hosts a variety of applications
  Single OS process, multiple applications in the same object space (image)
- . . . that makes it easy to experiment (*exploratory programming*)
  Try out new stuff and see what happens (Live programming, inspector, . . .)
- . . . that promotes modularity[1]
  (composability, decomposability, understandability)

[1] B. Meyer: Object-Oriented Software Construction

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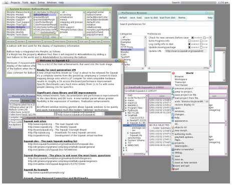

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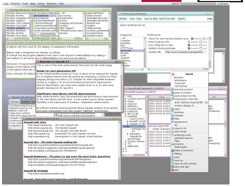

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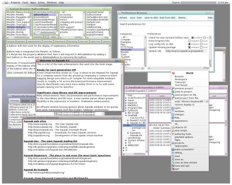

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  Think of the programming language as an operating system
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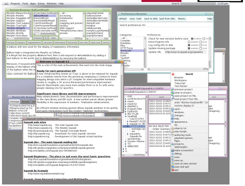

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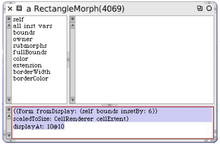

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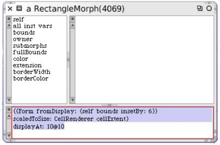

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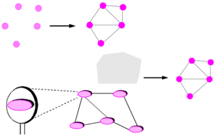

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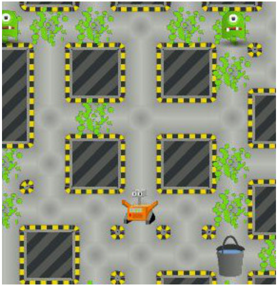
Matriona

Running Example: Space Cleanup



- All game objects are subclasses of `Morph`
- Game is built using `Morph` composition
- Classes: `Item`, `Player`, . . .

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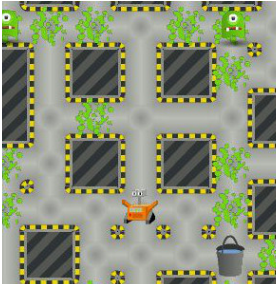

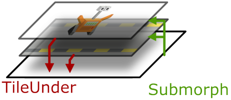

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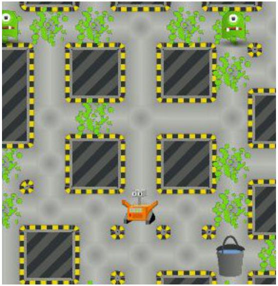

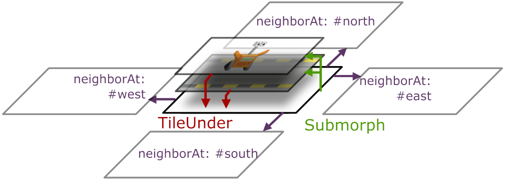

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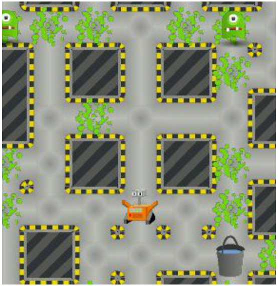

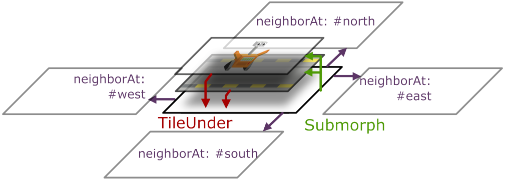

```
class Level extends Morphic.Morph {
    int stepTime() { return 1000; }
}
```

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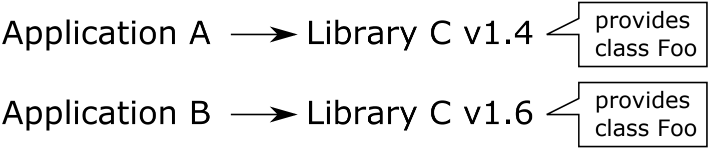
Module Versioning

- **Goal:** Run a variety of applications, composability
- **Dependency Conflicts:** Multiple applications require the same dependency in different versions



Application A → Library C v1.4 — provides class Foo

Application B → Library C v1.6 — provides class Foo

- **Problem:** Naming conflicts between versions

Module Versioning

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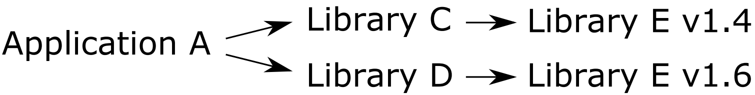
Application A

Library C

Library D

Library E v1.4

Library E v1.6

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Module Versioning

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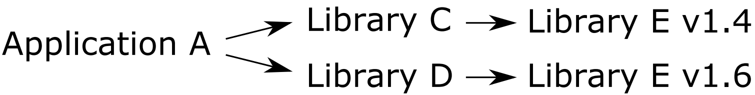


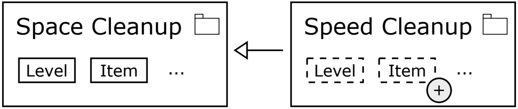
Application A → Library C → Library E v1.4

Application A → Library D → Library E v1.6

- **Application Upgrade:** Install both versions, then perform upgrade (possibly live upgrade)
- **Problem:** Naming conflicts between versions

Module Inheritance

- **Goal:** Exploratory programming, decomposability
- **Task:** Add unforeseen variation points. Design variants of Space Cleanup, where ...
  - the speed of the game can be adjusted (overwrite `Level»stepTime`)
  - items can deal damage (add methods to all items)



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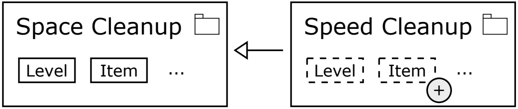
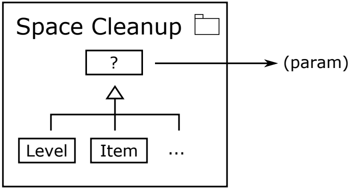


- **Design Constraints:** Apply changes to the original application automatically, leave the original application intact

External Configuration

- **Goal:** Exploratory programming, composability
- **Task:** Design a variant of Space Cleanup, where a UI framework implementation is passed as an argument



- **Problem:**
  - UI elements are subclasses of `Morphic.Morph`
  - Dependency cannot simply be passed as argument to constructor/factory method, because class hierarchy depends on it

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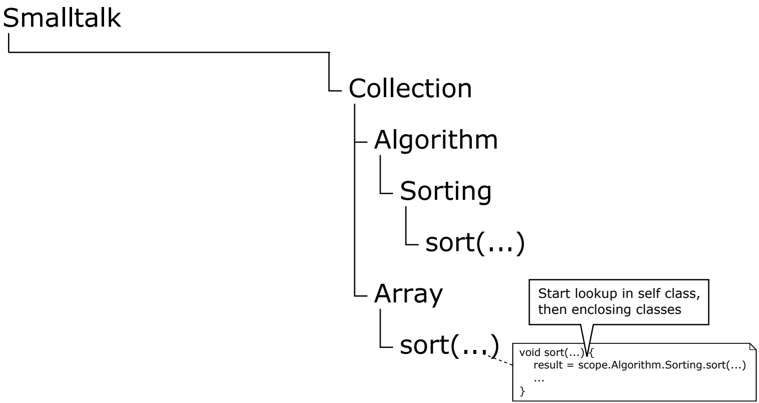
Mechanism

- Classes can have variables, methods, and **nested classes**
- Nested classes are . . .
  - . . . class-side members
  - . . . accessed using message sends
  - . . . can have parameters (accessed using message sends to class object)
- Top-level class is called *module*

Name Lookup Example (1/4)



Smalltalk

Collection

Algorithm

Sorting

sort(...)

Array

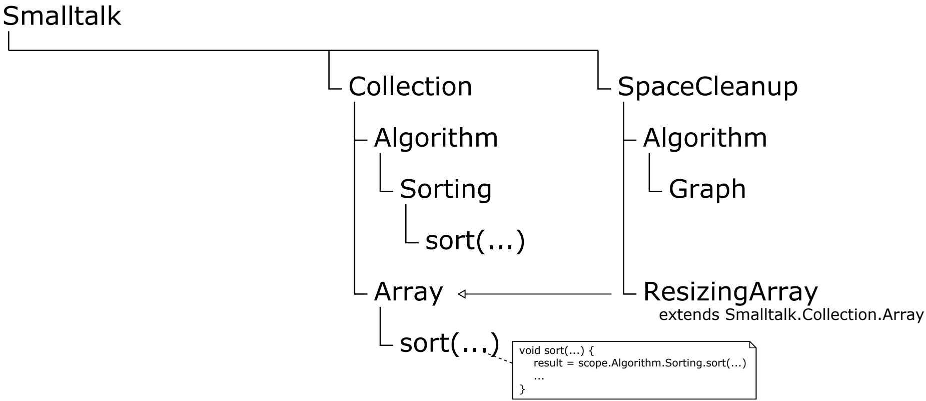
sort(...)

Start lookup in self class, then enclosing classes

```
void sort(...) {
    result = scope.Algorithm.Sorting.sort(...)
    ...
}
```

`scope.Algorithm` should resolve to `St.Collection.Algorithm`

Name Lookup Example (2/4)



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void sort(...) {
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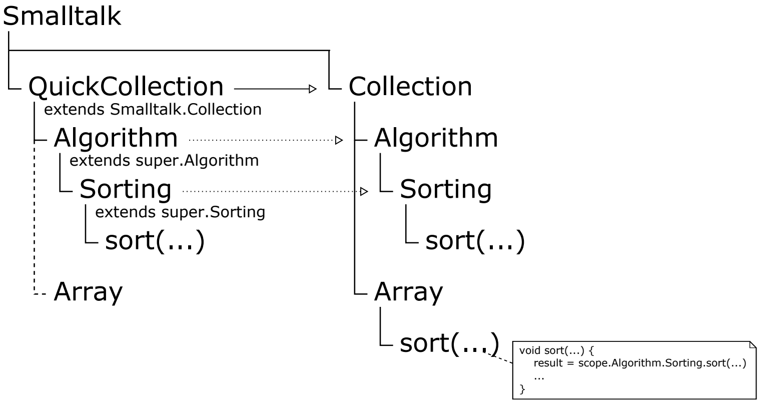
}
```

`St.Scu.ResizingArray.sort`: `scope.Algorithm` should resolve to `St.Collection.Algorithm`

Name Lookup Example 3/4



Smalltalk

QuickCollection
extends Smalltalk.Collection

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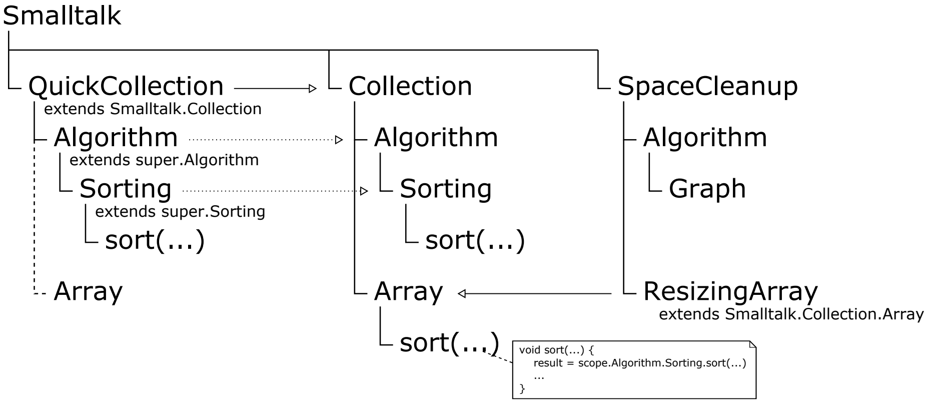
`St.QC.Array.sort`: `scope.Algorithm` should resolve to `St.Collection.Algorithm`

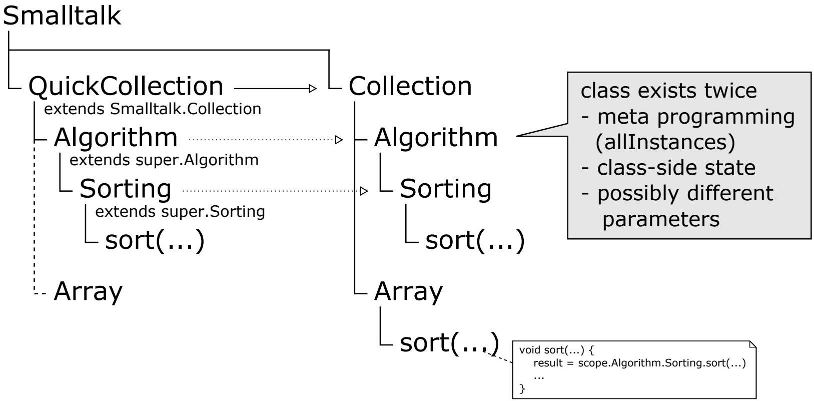
Name Lookup Example 4/4



```
void sort(...) {
   result = scope.Algorithm.Sorting.sort(...)
   ...
}
```

- `scope.Algorithm` is late bound and can refer to classes, methods, parameters
- Name lookup mechanism determines which `Algorithm` to choose

Inherited Class Copies



class exists twice
- meta programming (allInstances)
- class-side state
- possibly different parameters

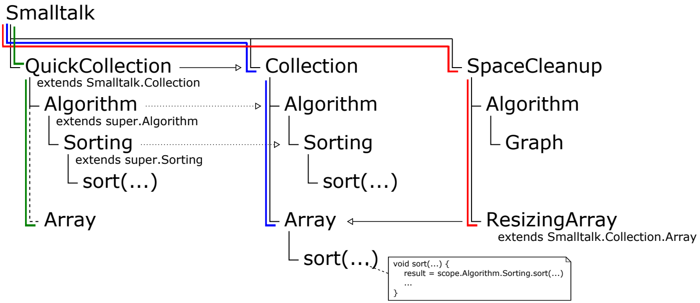
```
void sort(...) {
   result = scope.Algorithm.Sorting.sort(...)
   ...
}
```

- *super*(`St.QC.Algorithm`) is an *inherited class copy* of `St.C.Algorithm`
- Notation: `St.QC.Algorithm[St.C.Algorithm]`

High-level Idea

- **Idea:** Generalize method lookup to class nesting hierarchies
- **Standard Method Lookup:**
  $sub(C)$ can override methods defined in C
- **Nesting-aware Name Lookup:**
  - $sub(C)$ can override names defined in C
  - $sub(enclosing(C))$ can override names defined in $enclosing(C)$
  - $sub(enclosing(enclosing(C)))$ can override names defined in $enclosing(enclosing(C))$
  - ...

Relative Name Lookup (1/2)



```
void sort(...) {
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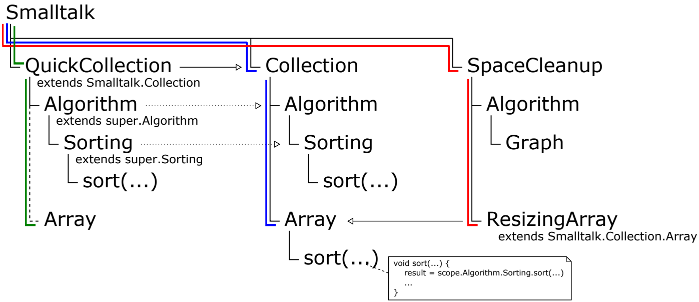
}
```

- *Lexical Class Nesting Hierarchy:* static hierarchy of enclosing classes
- *Run-time Class Nesting Hierarchy:* dynamic hierarchy of enclosing classes, taking into account run-time (polymorphic) type of receiver
- $L = (\texttt{St.C.Array}, \texttt{St.C}, \texttt{St})$
- $R_1 = (\texttt{St.QC.Array[St.C.Array]}, \texttt{St.QC}, \texttt{St})$
- $R_2 = (\texttt{St.Scu.ResizingArray}, \texttt{St.Scu}, \texttt{St})$

Relative Name Lookup (2/2)



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Collection
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SpaceCleanup
Algorithm
Graph
ResizingArray
extends Smalltalk.Collection.Array

```
void sort(...) {
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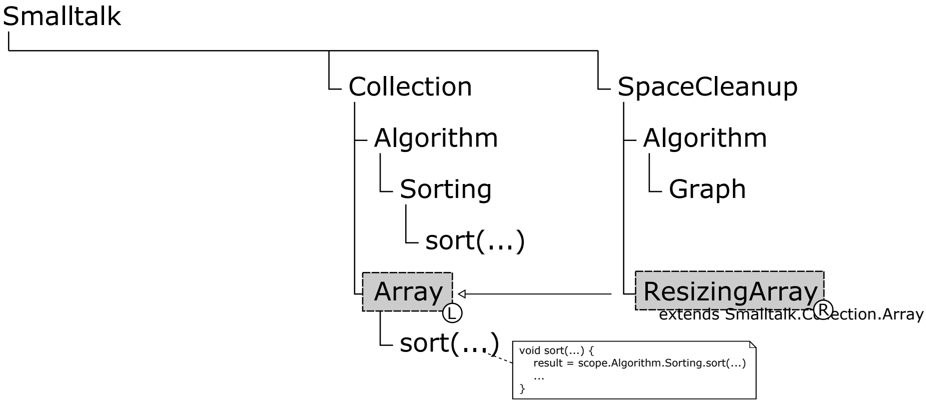
}
```

Traverse both lexical (L) and run-time class nesting hierarchy (R) in parallel (R takes precedence), as long as one of the following is true, where $l \in L$ and $r \in R$.

- $r = l$
- r is a subclass of l, i.e., $r \rhd l$
- r is an inherited class copy of l, i.e., $r \leadsto l$
- r is a subclass of an inherited class copy of l, i.e., $r \rhd_{\leadsto} l$

Example: Relative Name Lookup (1/2)



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extends Smalltalk.Collection.Array

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void sort(...) {
   result = scope.Algorithm.Sorting.sort(...)
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`St.Scu.ResizingArray` ▷ `St.C.Array` (→ R, L)

Lookup fails in both `R` and then `L`

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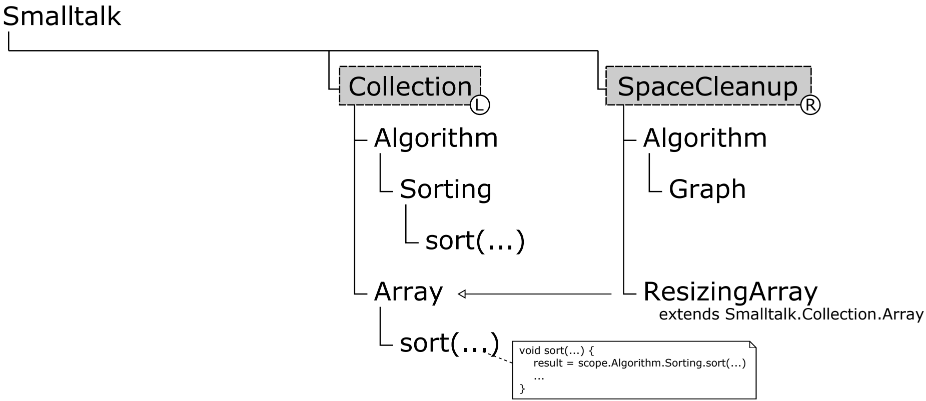

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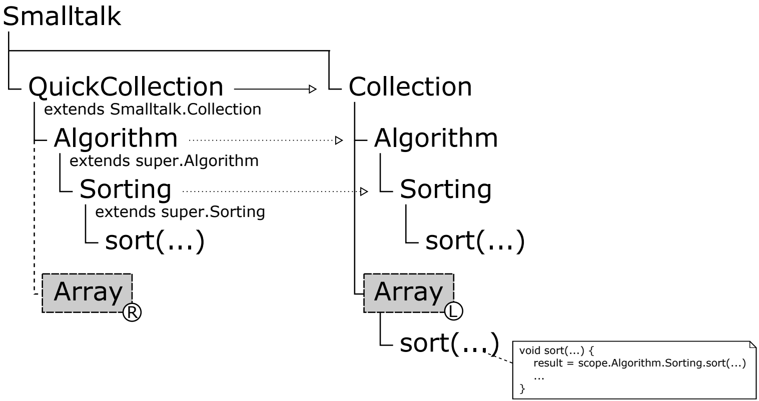
$$\texttt{St.Scu}\ \neg\{=, \rhd, \rightsquigarrow, \rhd_{\rightsquigarrow}\}\ \texttt{St.C} \qquad (\rightarrow \mathrm{L})$$

Lookup succeeds in $\texttt{L}$

Example: Relative Name Lookup (2/2)



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void sort(...) {
   result = scope.Algorithm.Sorting.sort(...)
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}
```
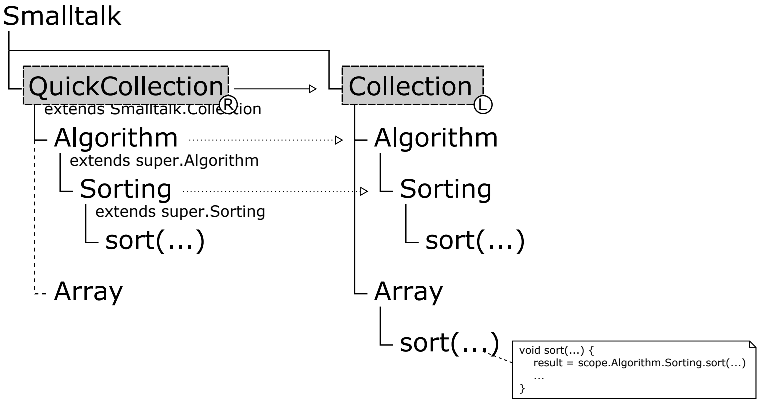

$\texttt{St.QC.Array} \leadsto \texttt{St.C.Array}$ $(\rightarrow \mathrm{R}, \mathrm{L})$

Lookup fails in both R and then L

Example: Relative Name Lookup (2/2)



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$\texttt{St.QC} \triangleright \texttt{St.C}$ $(\rightarrow \text{R, L})$

Lookup succeeds in $\texttt{R}$

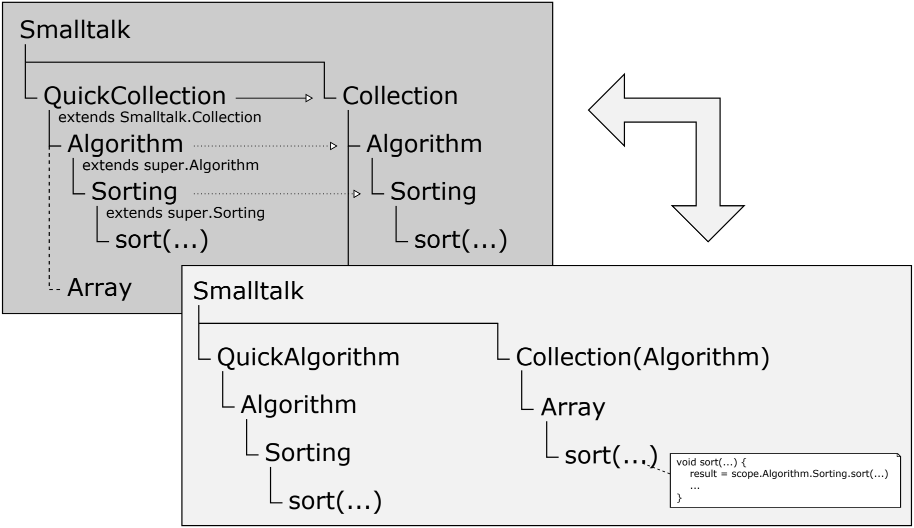
Class Nesting Details

- Lookup mechanism is **similar to Java**, differs from Newspeak (lookup in `self class`, then superclasses, then enclosing class and superclasses, etc.)
- Nested classes are **virtual** and can be overridden
- Lookup mechanism looks up **methods and nested classes** (and parameters)
- `extends` supports **arbitrary expressions**
- Overwritten and original nested classes do **not have to be in a subclass/subtype relationship** (c.f. Jx, gbeta)

Class Parameterization (1/2)

- Must provide argument to obtain concrete class object
- Different class object for every *instantiation* (c.f. C++ templates)
- Access parameter value via message send to class object
- Same name lookup mechanism
- Name lookup precedence (→ shadowing)
    1. Method in *r*
    2. Parameter in *r*
    3. Class in *r*
    4. Method in *l*
    5. Parameter in *l*
    6. Class in *l*

Class Paramterization (2/2)



Smalltalk

QuickCollection

extends Smalltalk.Collection

Algorithm

extends super.Algorithm

Sorting

extends super.Sorting

sort(...)

Array

Collection

Algorithm

Sorting

sort(...)

Smalltalk

QuickAlgorithm

Algorithm

Sorting

sort(...)

Collection(Algorithm)

Array

sort(...)

```
void sort(...) {
   result = scope.Algorithm.Sorting.sort(...)
   ...
}
```

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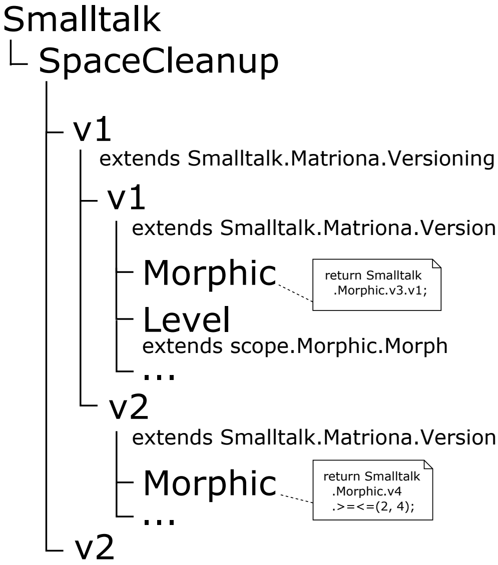
Module Versioning



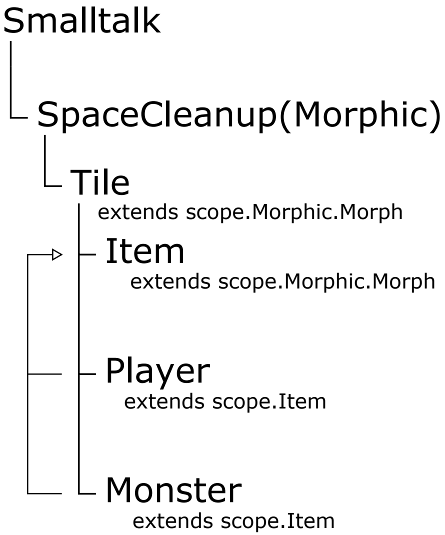
- Smalltalk
  - SpaceCleanup
    - v1
      extends Smalltalk.Matriona.Versioning
      - v1
        extends Smalltalk.Matriona.Version
        - Morphic

          ```
          return Smalltalk
           .Morphic.v3.v1;
          ```
        - Level
          extends scope.Morphic.Morph
        - ...
      - v2
        extends Smalltalk.Matriona.Version
        - Morphic

          ```
          return Smalltalk
           .Morphic.v4
           .>=<=(2, 4);
          ```
        - ...
    - v2

- Convenience methods: <, <=, >, >=, <>, <=>, <>=, <=>=, `latest`
- Name lookup finds classes, parameters, and **methods**
- `Morphic` is an import

External Configuration (1/2)



Smalltalk

SpaceCleanup(Morphic)

Tile
extends scope.Morphic.Morph

Item
extends scope.Morphic.Morph

Player
extends scope.Item

Monster
extends scope.Item

- Decouple implementation from dependencies
- `Morphic` parameter should implement Morphic interface

External Configuration (2/2)

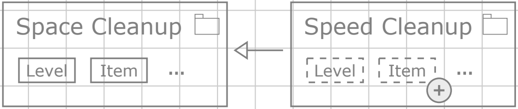
```
class Smalltalk {
  class SpaceCleanup<Morphic implements Smalltalk.Morphic.Interface> {
    class Tile extends scope.Morphic.Morph {
      class Item extends scope.Morphic.Morph { /* ... */ }
      class Player extends scope.Item { /* ... */ }
      class Monster extends scope.Item { /* ... */ }
    }

    static void run() { /* ... */ }
  }
}

Smalltalk.SpaceCleanup<Smalltalk.NativeRendering>.run();
```

Module Inheritance

- **Task:** Design variants of Space Cleanup, where . . .
  - **the speed of the game can be adjusted (overwrite `Level»stepTime`)**
  - items can deal damage (add methods to all items)



- **Design Constraints:** Apply changes to the original application automatically, leave the original application intact

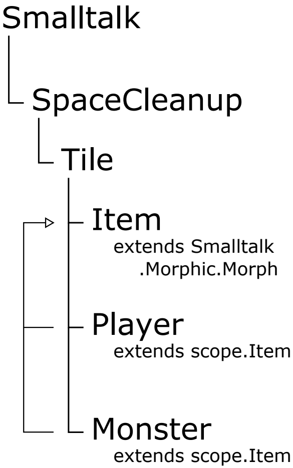
Module Inheritance: Speedy Space Cleanup

```
class Smalltalk {
 class SpaceCleanup {
  Level currentLevel;
  class Level { /* ...  */ }
 }

 class SpeedySpaceCleanup extends scope.SpaceCleanup {
  @Override class Level extends super.Level {
   int stepTime;
   @Override int stepTime() { return stepTime; }
  }

  void setSpeed(int stepTime) {
   currentLevel.stepTime = stepTime;
  }
 }
}
```

Module Inheritance: Damage Space Cleanup (1/3)



Smalltalk

SpaceCleanup

Tile

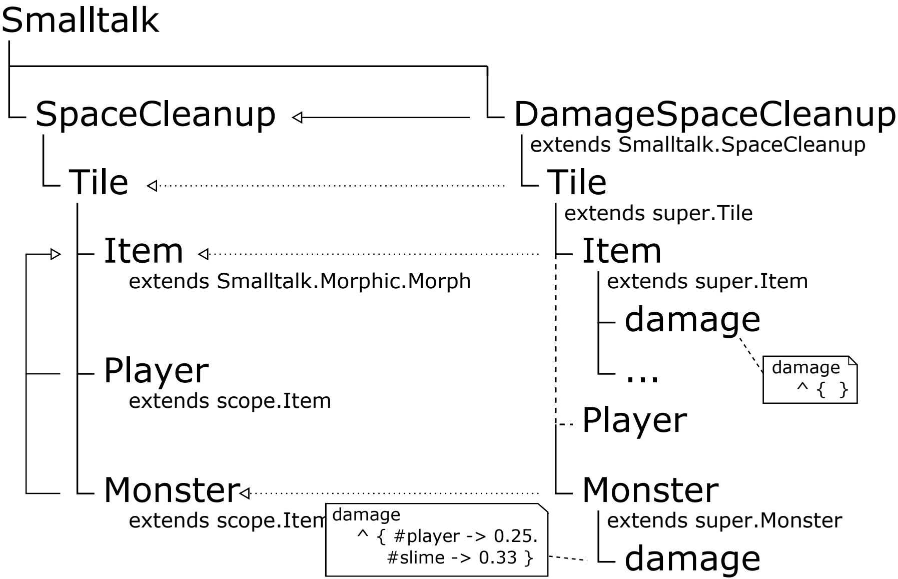
Item
extends Smalltalk
.Morphic.Morph

Player
extends scope.Item

Monster
extends scope.Item

- *Damage* functionality should be implemented in *items*
- Need to define subclasses of `Item` and `Monster`
- $\texttt{Monster}_{\text{dmg}}$ should inherit from both `Monster` and $\texttt{Item}_{\text{dmg}}$

Module Inheritance: Damage Space Cleanup (2/3)



Smalltalk

SpaceCleanup

Tile

Item
extends Smalltalk.Morphic.Morph

Player
extends scope.Item

Monster
extends scope.Item

DamageSpaceCleanup
extends Smalltalk.SpaceCleanup

Tile
extends super.Tile

Item
extends super.Item

damage

...

```
damage
    ^ { }
```

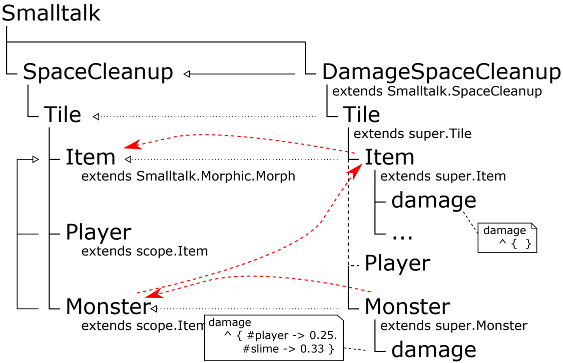
Player

Monster
extends super.Monster

damage

```
damage
    ^ { #player -> 0.25.
        #slime -> 0.33 }
```

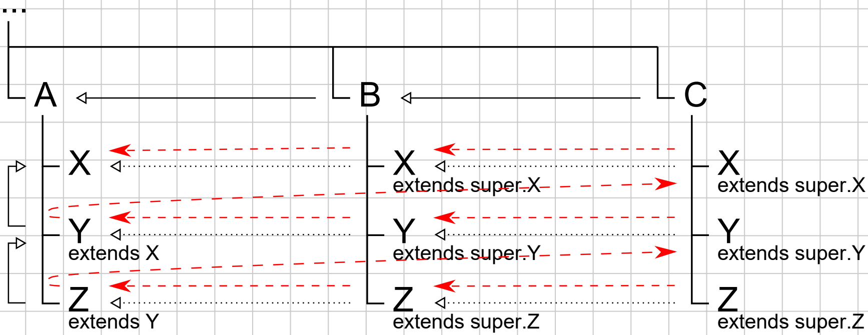
Module Inheritance: Damage Space Cleanup (3/3)



Resulting superclass hierarchy of `Monster`$_{\text{dmg}}$:

1. `St.DScu.Tile.Monster[St.Scu.Tile.Monster]`
2. `St.DScu.Tile.Item`
3. `St.DScu.Tile.Item[St.Scu.Tile.Item]`
4. `St.Morphic.Morph`

Generalization: More than 2 Hierarchies



- Effectively implements multiple inheritance
- Related work: Mixin layers

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Conclusion

- **Vision for Matriona:** support long-living systems, multiple applications in one execution environment, exploratory programming, modularity (composability, decomposability, understandability)
- **Techniques:** Module versioning, module inheritance, external configuration
- **First steps:** A module system that . . .
  - hosts modules in various versions (→ composability, long-living systems)
  - makes it easy to design module variants (→ exploratory programming, decomposability)
- **Next steps:**
  - Migration of running applications (state/object migration)
  - Class extensions (backward compatibility)[1]
  - Method/class visibility (modular protection)

[1] LASSY workshop: Hierarchical Layer-based Class Extensions in Squeak/Smalltalk