Traits in C#

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Roadmap

- Project Context / Why Traits ?
- What's a Trait ? Flattening Traits ?
- Traits in C# and STOO (**s**tatically **t**yped **o**bject **o**riented) Languages

Why Traits ?

Problem / Goal:

avoid *code duplication* and *fragile compositions*
share code easily

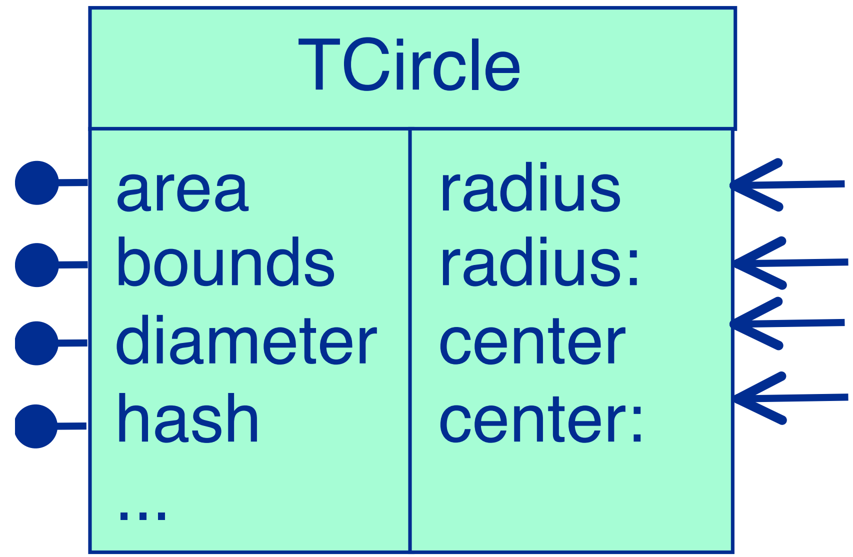
Current Reuse-Mechanisms:

Single Inheritance ? -- too *limited*
Multiple Inheritance ? } good, but too complex
Mixins ? } fragile composition, "*ripple effect*"

Solution: Traits -- simple, efficient, cool !

What is a “Trait” ?

- *first-class* compose-time *group of pure methods*

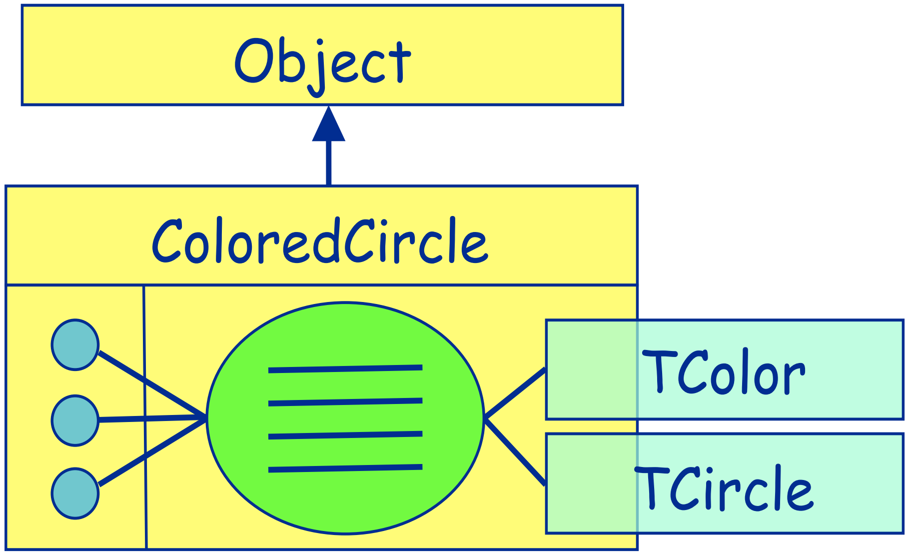


Properties:

- *stateless, pure behavior*
- *provides* ●— & *requires* ← a set of methods

Traits & Composition (1)

- *complements* single inheritance
- composition order is *irrelevant*
- *compose time* entity
- composite entity is in *full control of the composition*



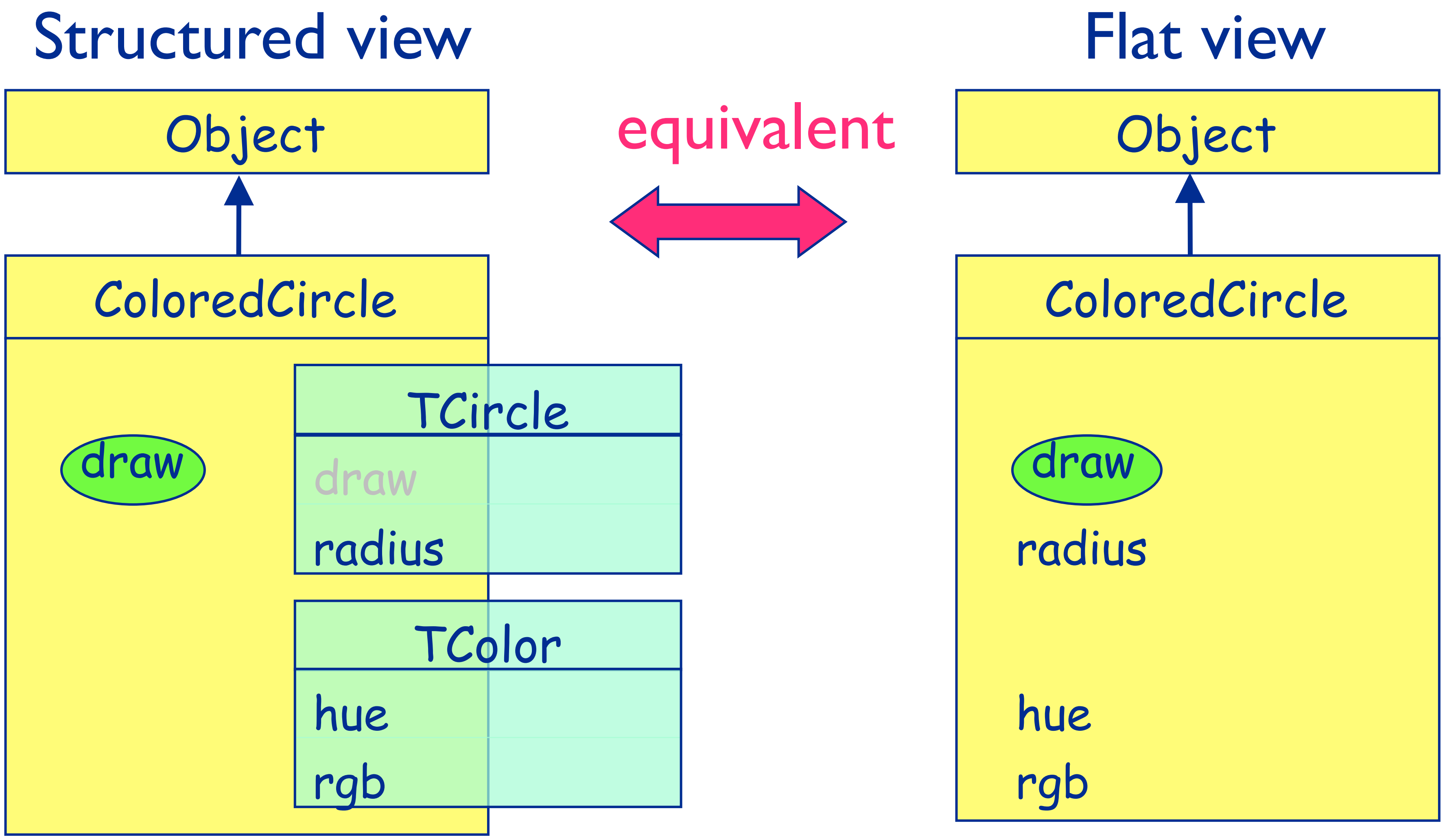
Class = Superclass + State
+ Traits + Glue methods

Traits & Composition (2)

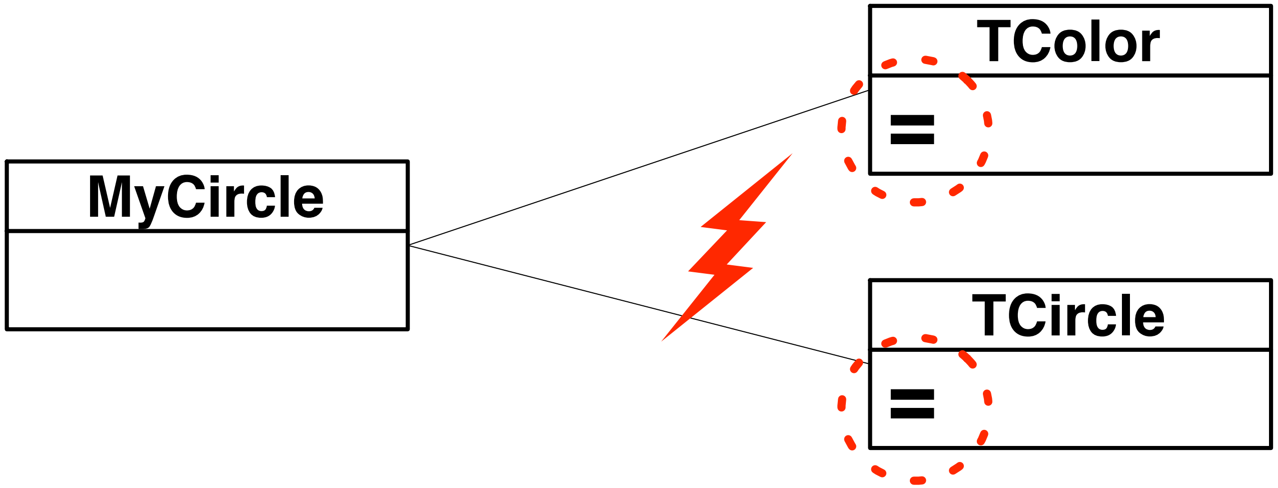
- class methods >>> trait methods
- *no change* in overriding !
- *self/this, super/base* have the *same meaning as before !*

= consequences by the *flattening property*

Flattening Traits



Traits & Conflicts (1)

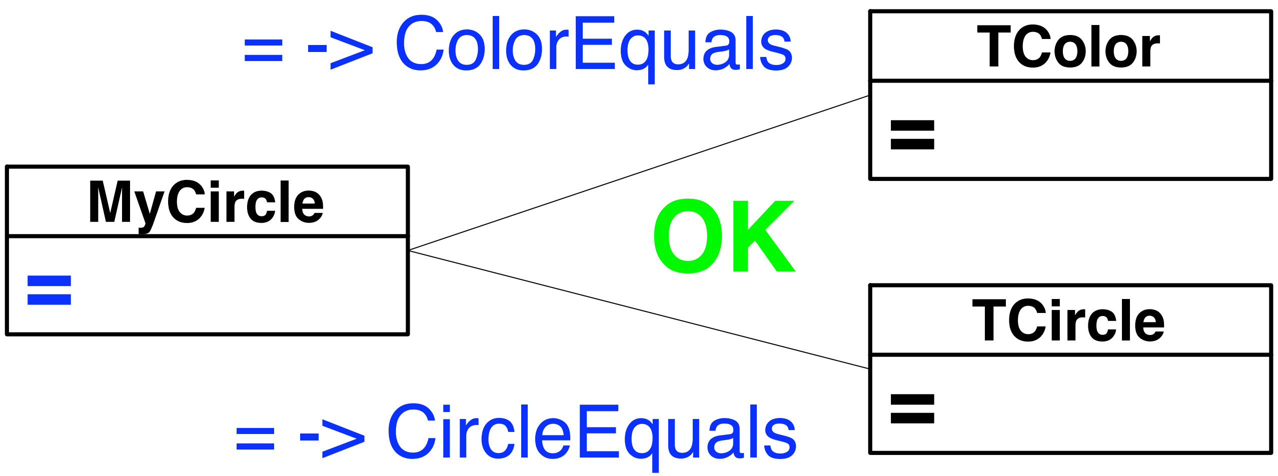


explicit conflict resolution by the composite entity

Alias -> and ***Exclusion ^***

Traits & Conflicts (2)

... one possible solution: **aliasing**

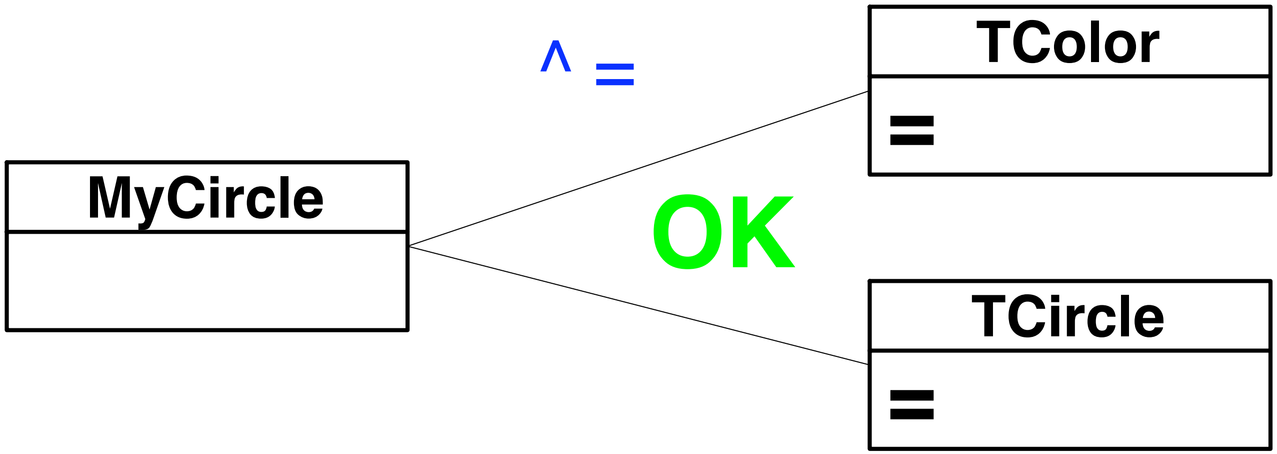


Traits & Conflicts (3)

```
class Circle {
  uses{
    TColor { = -> ColorEquals; };
    TCircle { = -> CircleEquals; };
  }
  public boolean operator =(Circle c) {
    return this.ColorEquals(c)
           && this.CircleEquals(c);
  }
}


trait TColor { ... }
trait TCircle { ... }
```

Traits & Conflicts (4)

... an alternative ? **exclusion**



Traits & Conflicts (5)

```
class Circle {
  uses{
    TColor { ^=; };
    TCircle;
  }
}

trait TColor { ... }
trait TCircle { ... }
```

Traits

- available in *dynamically typed oo languages*

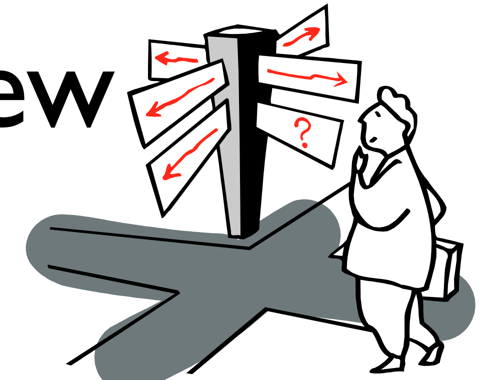
  → Smalltalk, Slate, Perl 6 (role)

  experiences: *simple* and *expressive*

- what about ***s**tatically **t**yped **oo** languages*, e.g. **C#** ???

  → Scala, MiniJava

Traits in C# : Overview



Trait *Container* and *Definition*
Typed *Syntax/Declaration* }

3 Kinds of Typed Traits in STOO languages

Generics and Generic Constraints

Typing Traits and *Type Problems*

Respect *modifiers* and *keywords*

Handling of *libraries* / *packages*

Trait *Interfaces*

... ...

Typed Syntax (1)

Typed Trait Declaration:

- typed *alias*, *exclusion* and *requirements*

Solution (conceptually simple):

- alias, exclusion → *argument* types
- requirements → *argument* (and *return*) types

Squeak / ST

```
Object subclass: #MyCircle
instanceVariableNames: 'color '
uses {
  TColor @{ #invertAliased->#invert }.
  TShape -{ #resize: }.
}
MyCircle>>color
  ^ color
```

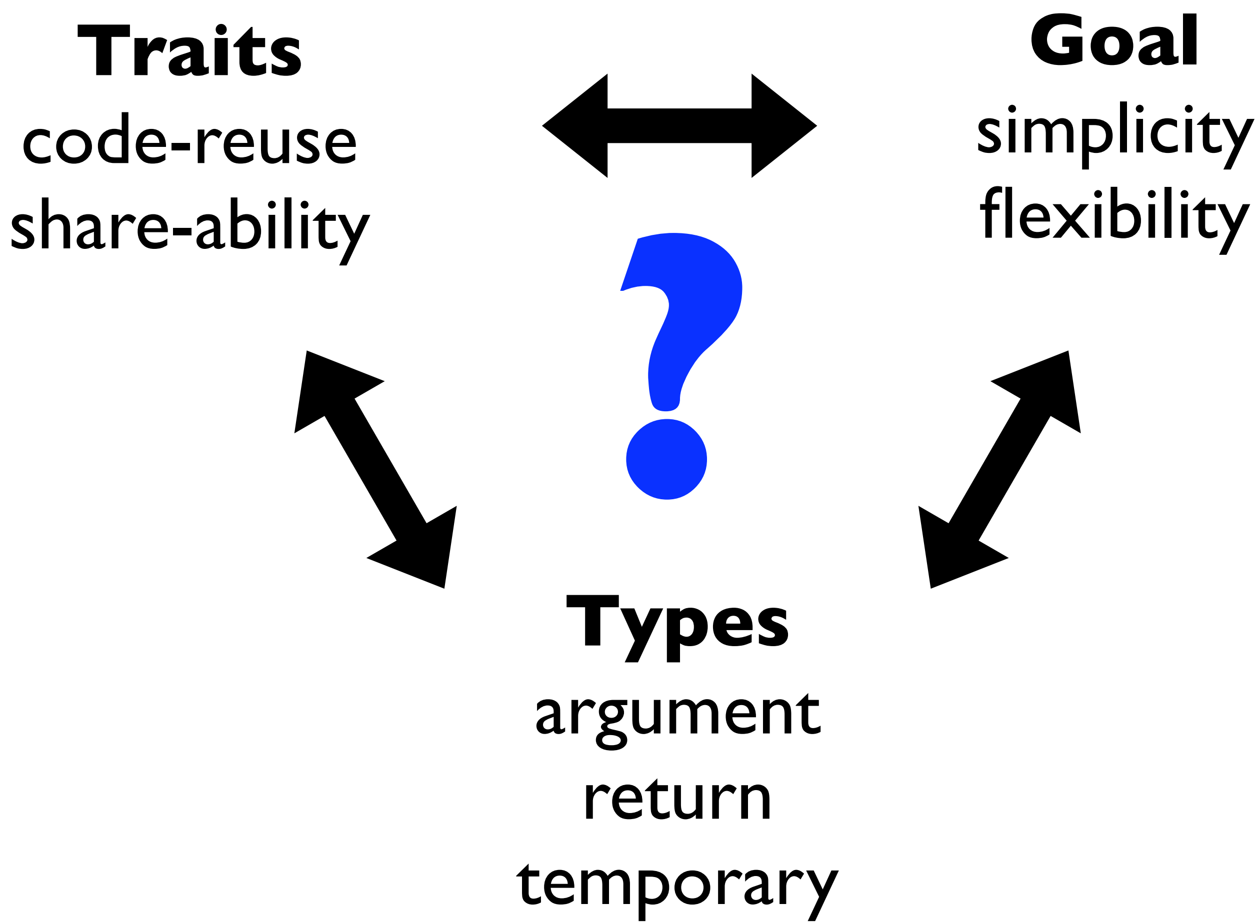
```
Trait named: #TColor
uses { }
requires { #color }
MyColor>>invert
  ^ ... self color ...
```

C#

```
public class MyCircle {
  uses {
    TColor {invert()->invertAliased;};
    TShape {^resize(int);};
  }
  private IColor color;
  public IColor Color() {
    return this.color;
  }
}
```

```
trait TColor {
  requires {
    IColor Color();
  }
  public IColor Invert() {
    ... return this.Color();
  }
}
```

Typing Traits (1)



Typing Traits (2)

Typed Trait methods

- what *argument* types ?
- what types should be *return*ed by methods ?
- how to return the *type of the class* using the trait ?
- *temporary* types ?

↔

Traits
code-reuse
share-ability
simplicity
flexibility

Typing Traits (3)

```
class MyCollection { uses {TSequenceable;} }

trait TSequenceable {
  public ??? Reverse() {
    ??? reversedList = new ???();
    ...
    return reversedList;
  }
  public void Concat(??? c1, ??? c2) {...}
}
```

Typing Traits (4)

Possible Solutions:

- Simple/Concrete types
- Interfaces
- Explicit / Parameterized ⟵
- Implicit / Type Keyword
- Implicit Types & Generics ⟵
- ...

Explicit / Parameterized

```
class MyCollection {
  uses { TSequenceable<MyCollection>; }   OR
  uses { TSequenceable<ICollection>; }
}

trait TSequenceable<A> {
  public A Reverse() {...}
  public void Concat(A.. c1, A.. c2) {...}
}
```

Explicit / Parameterized

Advantage:

- *simple*, *extremely flexible*
- *template-like* use, on top of any language

Disadvantage:

- multiple/variable use of the type parameter
- *inconsistent syntax/use* when generics are used

Implicit Types & Generics

```
class MyCollection<T> {
  uses { TSequenceable<T>; } ...
}

trait TSequenceable<A> {
  public TSequenceable Reverse() {...}
  public void Concat(TSeq.. c1, TSeq.. c2)
{...}
}
```

Implicit Types & Generics

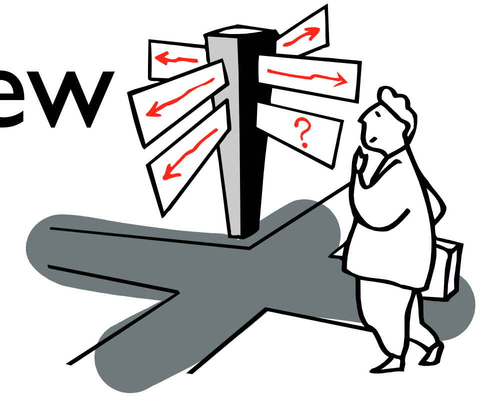
Advantage:

- *simple*
- *consistent syntax* for generics and non-generics

Disadvantage:

- *limited flexibility* for return types
- *not suitable for any use*

Traits in C# : Overview



Trait *Container* and *Definition*

Typed *Syntax/Declaration* } **~OK**

3 Kinds of Typed Traits in STOO languages

Generics and Generic Constraints

Typing Traits and *Type Problems* **~OK**

Respect *modifiers* and *keywords*

Handling of *libraries* / *packages*

Trait *Interfaces*

… …

Prototype Implementation (1)

- *Preprocessor* based on the *flattening property*
- *Simple Typed* and *Generic Traits*
  (no var-binding, strict-matchings only)
- Simple and minimal *Typed-Trait-syntax* for declarations and requirements
- ... ...

Prototype Implementation (2)

- *Generic parser* (most C-like languages supported)
- Simple CodeDOM framework
- Language-*independant flattening logic*

- … …

Future for Traits in C# / STOO

- Finding a *satisfying solution* for *modifier/keyword* and *typing problems*
- Combining Template-like & Generic Traits (?)
- Requirement constraints for methods (?)
- ... ...

- **Clean Implementation/Integration in *Rotor/.NET***

References (1)

N. Schärli, S. Ducasse, O. Nierstrasz, and A. Black. **Traits: Composable units of behavior**. In Proceedings ECOOP 2003 (European Conference on Object-Oriented Programming), volume 2743 of LNCS, pages 248–274. Springer Verlag, July 2003.

S. Ducasse, N. Schärli, O. Nierstrasz, R. Wuyts, and A. Black. **Traits: A mechanism for fine-grained reuse**. Transactions on Programming Languages and Systems, 2005. under revision.

References (2)

N. Schärli.
Traits — Composing Classes from Behavioral Building Blocks. PhD thesis, University of Bern, Feb. 2005.

O. Nierstrasz, S. Ducasse, and N. Schärli.
Flattening traits. Journal of Object Technology, 5(3):0–0, May 2006. To appear.

S. Reichhart
Traits in C#, Technical Report and prototype implementation, University of Bern, Switzerland, Sept. 2005

References (3)

Software Composition Group

Webpage

http://www.iam.unibe.ch/~scg/Research/Traits/index.html

Traits

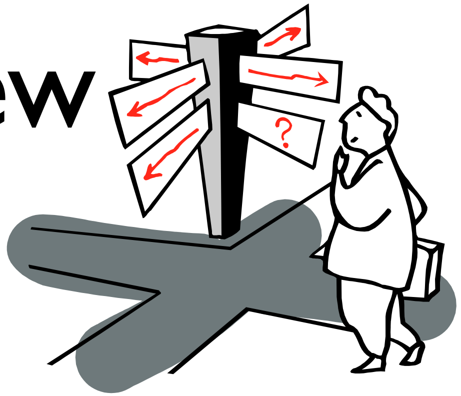
- ***simple*** **but** ***effective reuse-mechanism***

- ***no "ripple-effects"***

- ***no change*** **to the existing composition model (single inheritance, overriding, ...)**

- **fully-*controlled composition***

Traits in C# : Overview



Trait *Container* and *Definition* }

Typed *Syntax/Declaration* } **~OK**

3 Kinds of Typed Traits in STOO languages

Generics and Generic Constraints

Typing Traits and *Type Problems* **~OK**

Respect *modifiers* and *keywords*

Handling of *libraries* / *packages*

Trait *Interfaces*

… …

3 Kinds Of Traits

- Simple Traits
- Template-like traits
- (full) Generic Traits

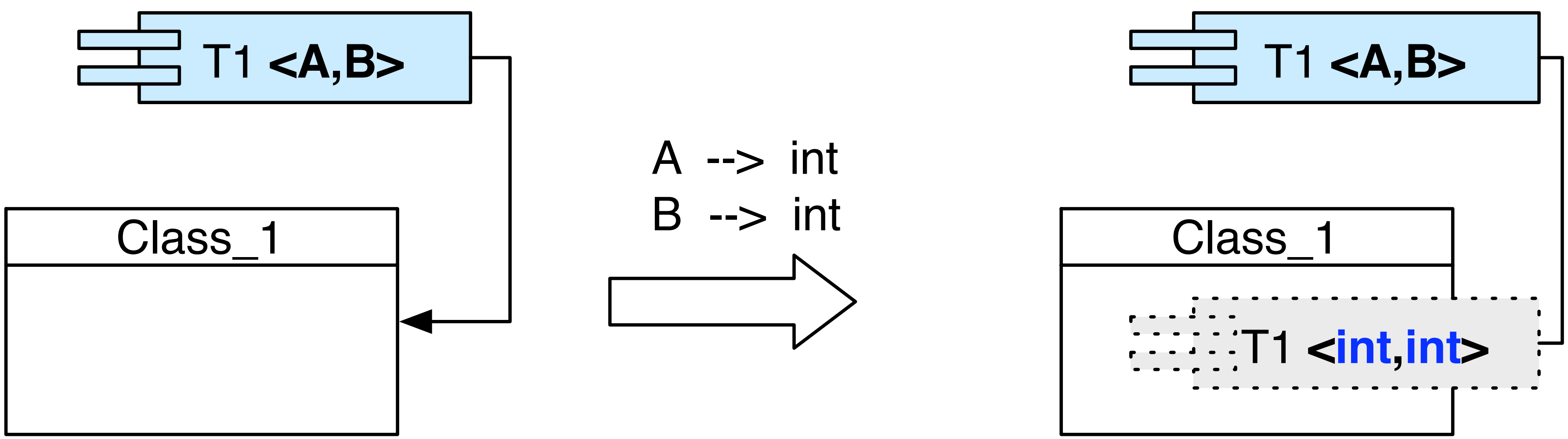
Simple Traits

- uses *identities* of *concrete argument*- and *return types*
- *type-problems* not handled
- very simple, but *limited* code reuse

```
class MyCollecion {
  uses { TSequenceable; } ...
}

trait TSequenceable {
  public ICollection Reverse() {...}
  public void Concat(IC.. c1, IC.. c1) {...}
}
```

Template-like Traits (1)

- not like C++ templates !
- simple, variable, *flexible type parameter*
- *type-problems* might be handled



Template-like Traits (2)

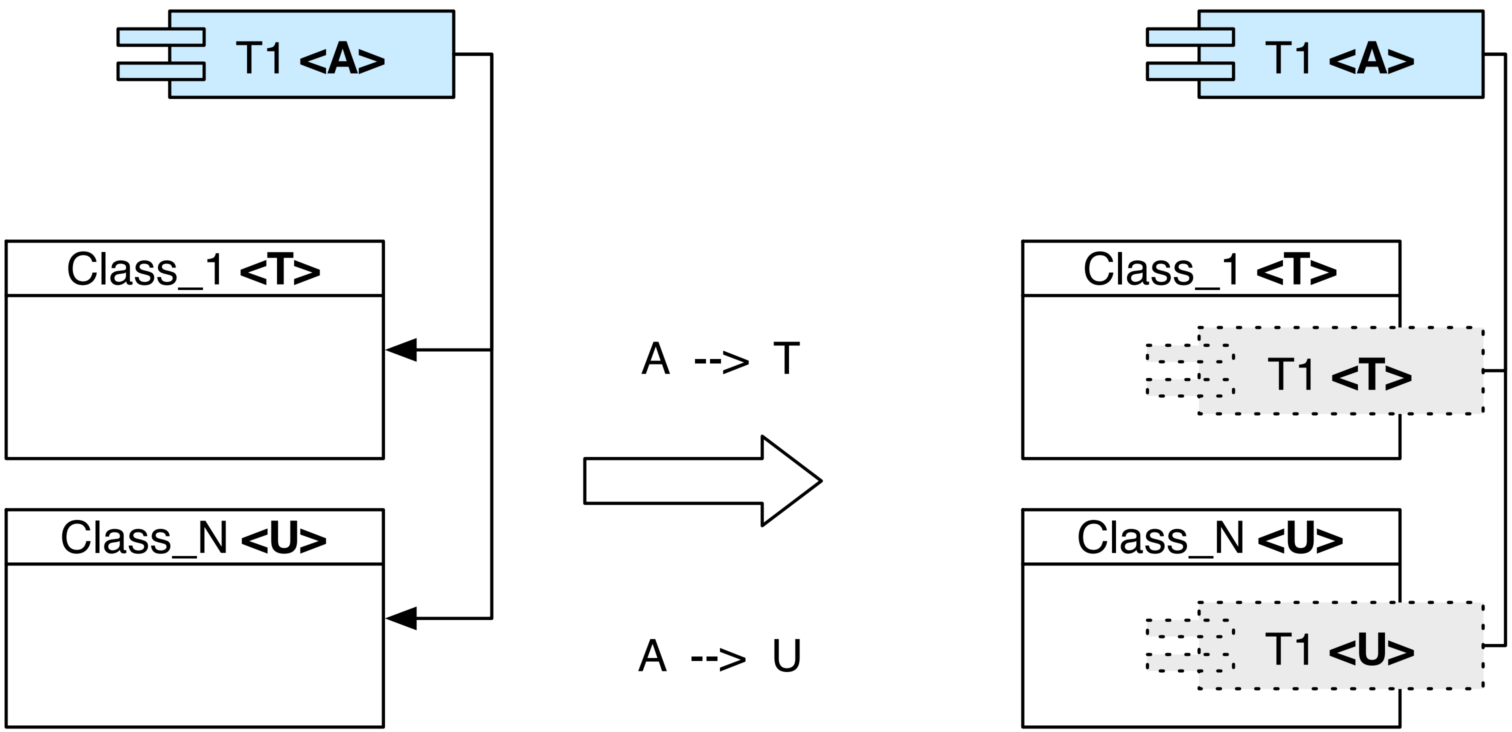
```
class MyCollection {
  uses { TSequenceable<ICollection>; } ...
}

trait TSequenceable<A> {
  public A Reverse() {...}
  public void Concat(A c1, A c1) {...}
}
```

or like this ...

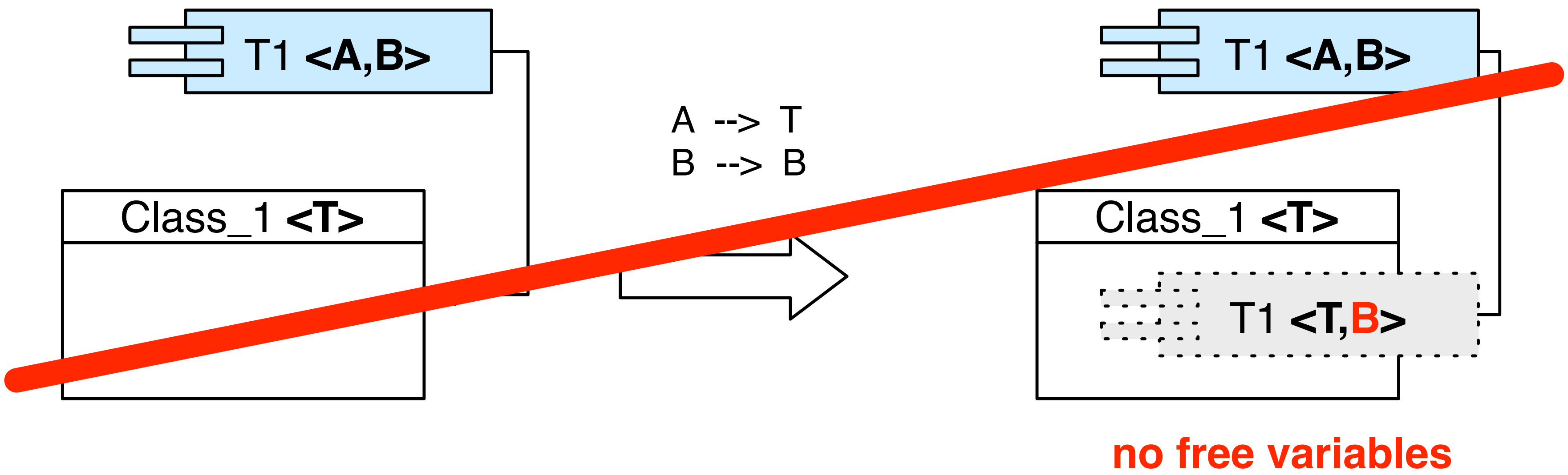
```
class MyCollection {
  uses { TSequenceable<MyCollecion>; } ...
}
```

Generic Traits (1)

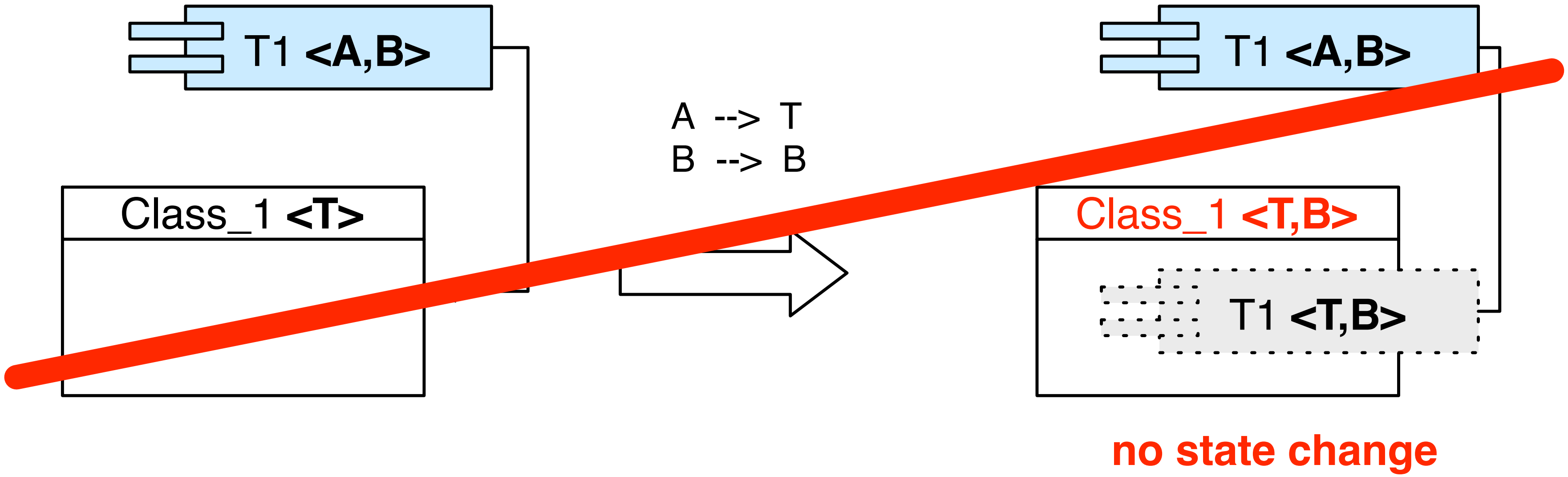
- parametric Polymorphism, *flexible* code reuse
- variable binding, a bit *more complex ...*



Generic Traits (2)



Generic Traits (3)



Generic Traits (4)

genericTypeParameters(class)

>=

∑(genericTypeParameters(Ti))

not more or *no 'different' generic type parameters*

Generic Traits (5)

```
class MyCollection<T> {
  uses { TSequenceable<T>; } ...
}

trait TSequenceable<A> {
  public ??? Reverse() {...}
  public void Concat(??? c1, ??? c1) {...}
}
```

??? type-problems

Modifiers / Keywords (C# only)

Trait Properties:

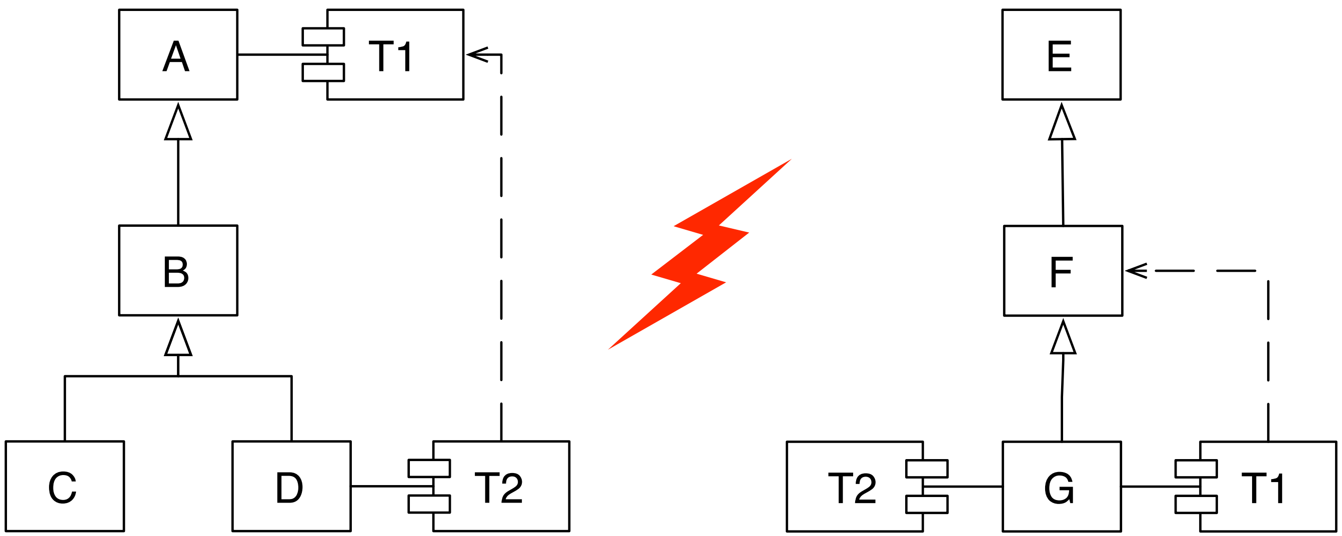
trait methods may want/need to *override/hide* methods of higher levels (classes or traits)

C#'s explicitly:

all methods must declare correct *inheritance* (and *accessibility modifiers*)

virtual, override, new, public, ...

Modifiers / Keywords (2)



Problem & Disadvantage:

- code sharing is *limited*
- might lead to *code duplication* (again)

Modifiers / Keywords (3)

Solution Basics:

tests should *catch conflicts* when processing traits
but: not a real solution to the problem ...

Possible solutions:

- Explicit modifiers for trait declaration ?
- Implicit resolution ?
- Avoid overriding traits ?
- ?

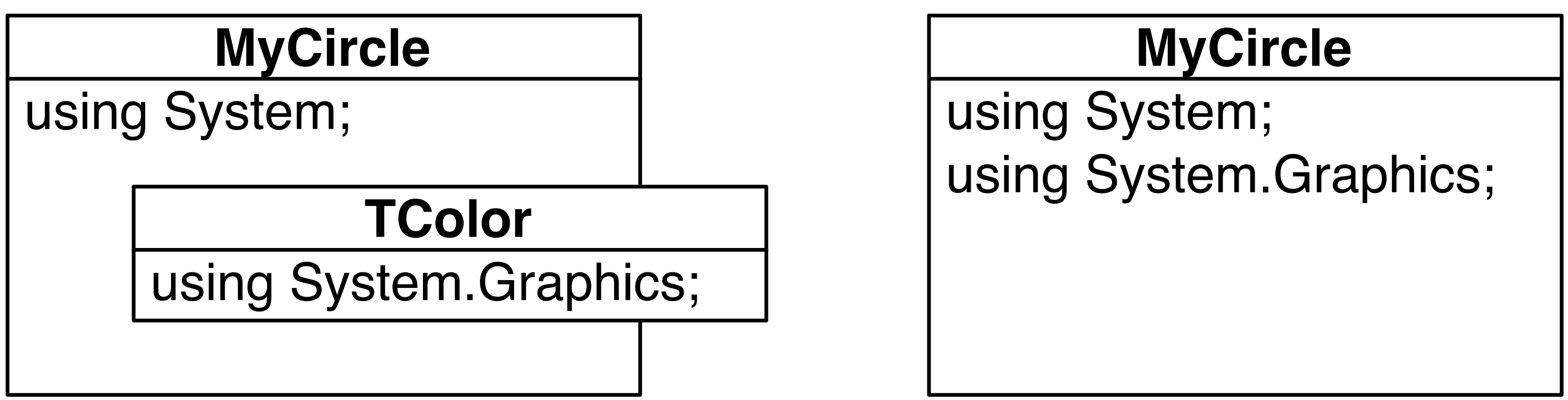
Library / Package propagation

Situation

Traits may also *depend on libraries*

Solution

implicit propagation of libraries to the higher level



Trait Interfaces (1)

Situation:

Traits may also *implement interfaces*

```
class MyShape { uses {TColor; } ... }
trait TColor : IColorable { ... }
```

Solution:

implicit propagation of interfaces to the higher levels

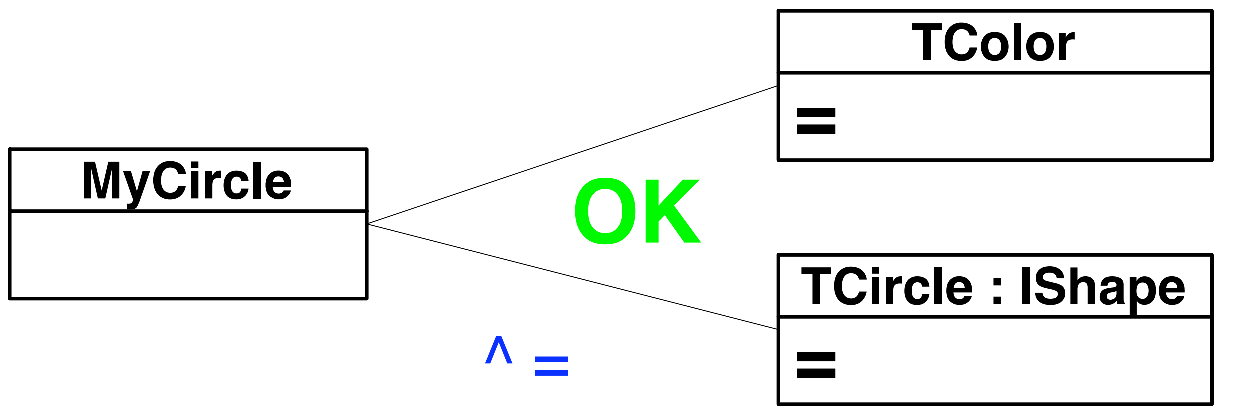
```
class MyShape : IColorable { ... }
```

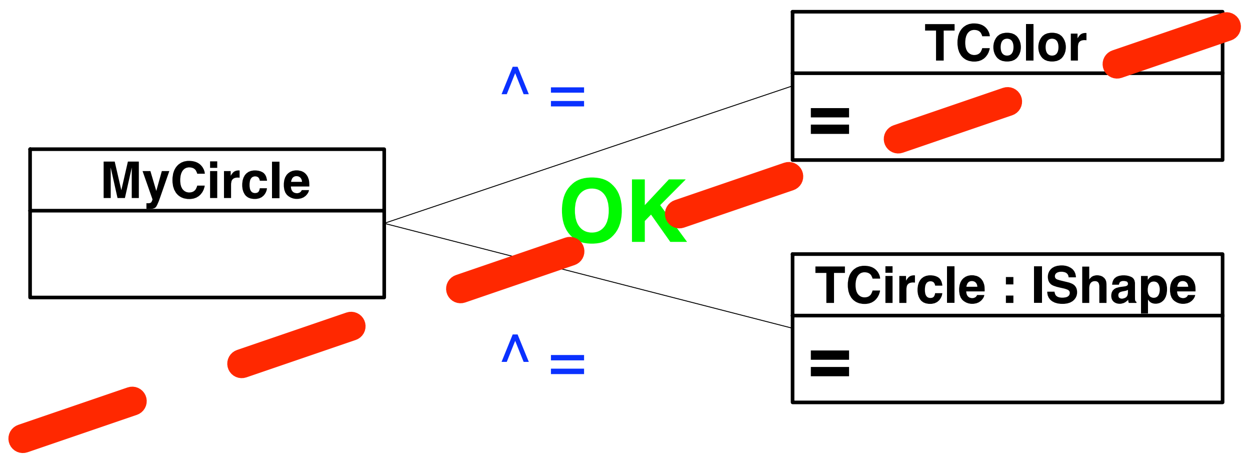
Trait Interfaces (2)

Advantage:
no explicit interface declaration / maintainance

!!! **Special Case**: Interfaces used with Exclusion
Confusing but correct, no breaking of the interface !

Trait Interfaces (3)





Generic Constraints (C# only)

Situation

Traits may also *use constraints* on generic type parameters

```
trait TSequenceable<T>
            where T : INumber {...}
```

Generic Constraints (2)

Solution

Test if constraints collide with constraints on higher levels

constraints(class) >= ∑(constraints(Ti))

not more, *not more 'restrictive'* or *different* constraints

Generic Constraints (3)

```
class MyRational<T> where T : IInteger {...}
trait MyAlgebra<A> where A : IFloatingPoint {...}
```

```
class MyDictionary<T> where T : IAssociation {...}
trait MySequence<A> where A : INumber {...}
```

Generic Constraints (4)

```
class MyDictionary<T> where T : IAssociation {...}
trait MySequence<A> where A : IAssociation,
ILockable {...}
```

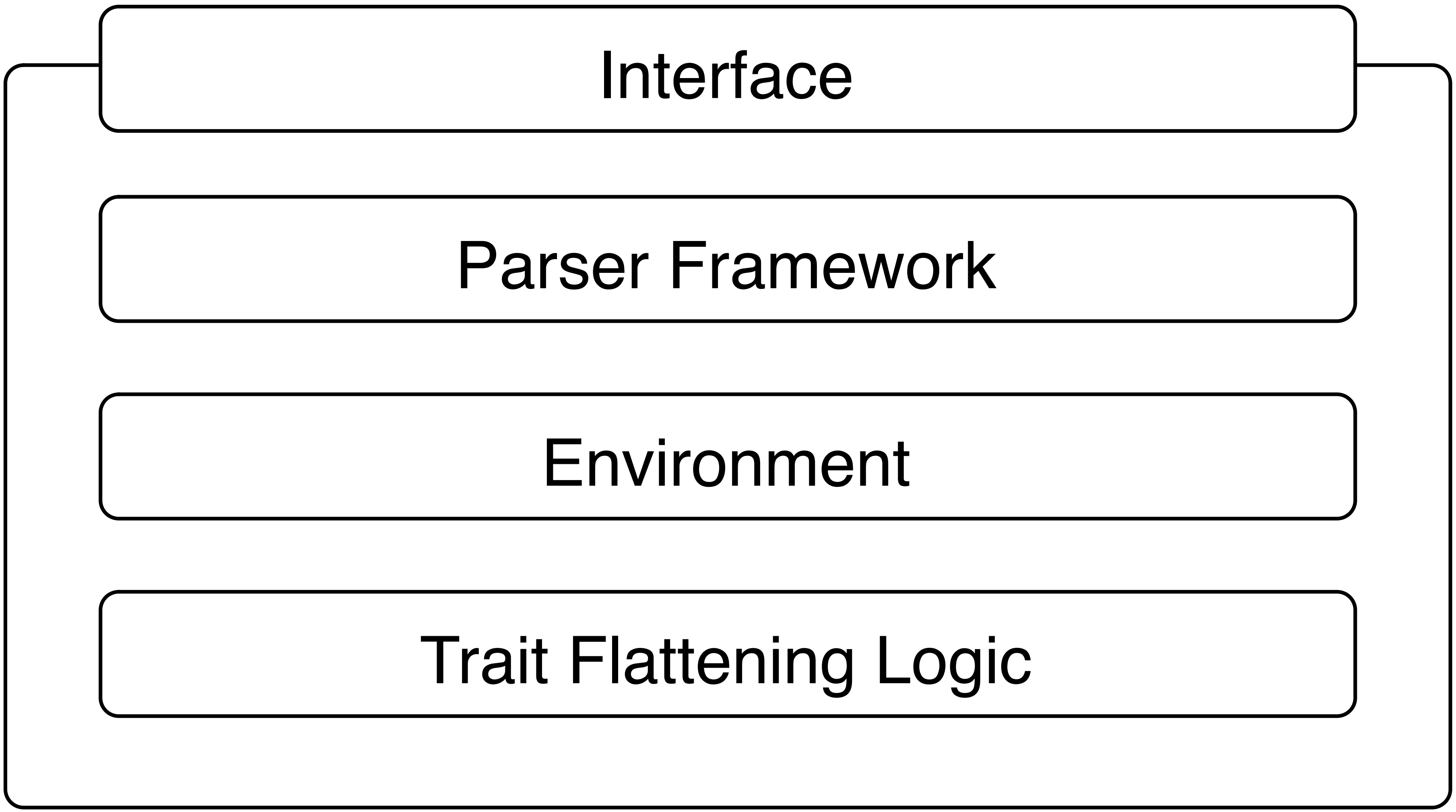
```
class MyRational<T> where T : IFloatingPoint {...}
trait MyAlgebra<A> where A : IInteger {...}
```

Generic Constraints (5)

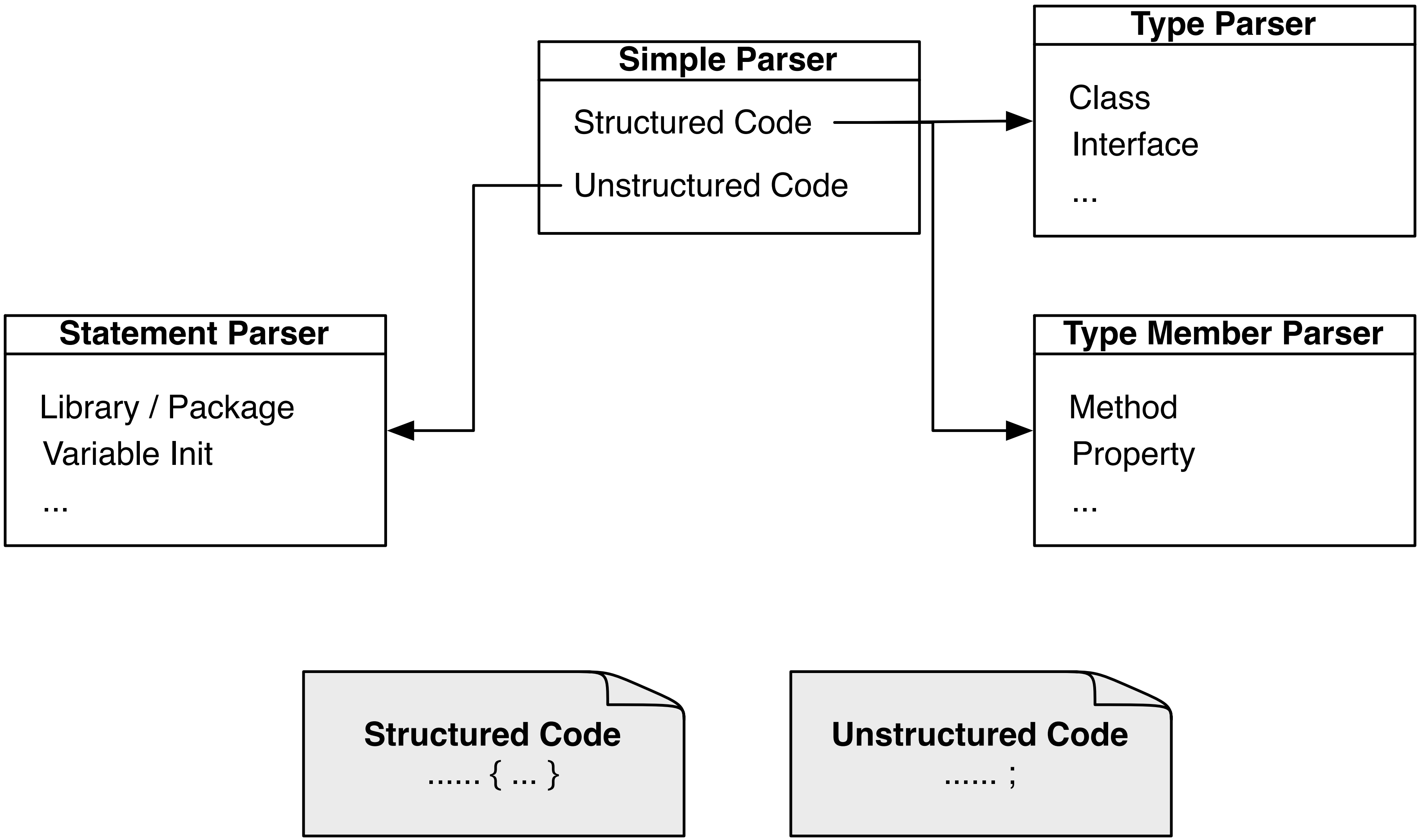
Disadvantage:

- Constraints *may prevent the ability to share behavior* easily
- Use is questionable (?)

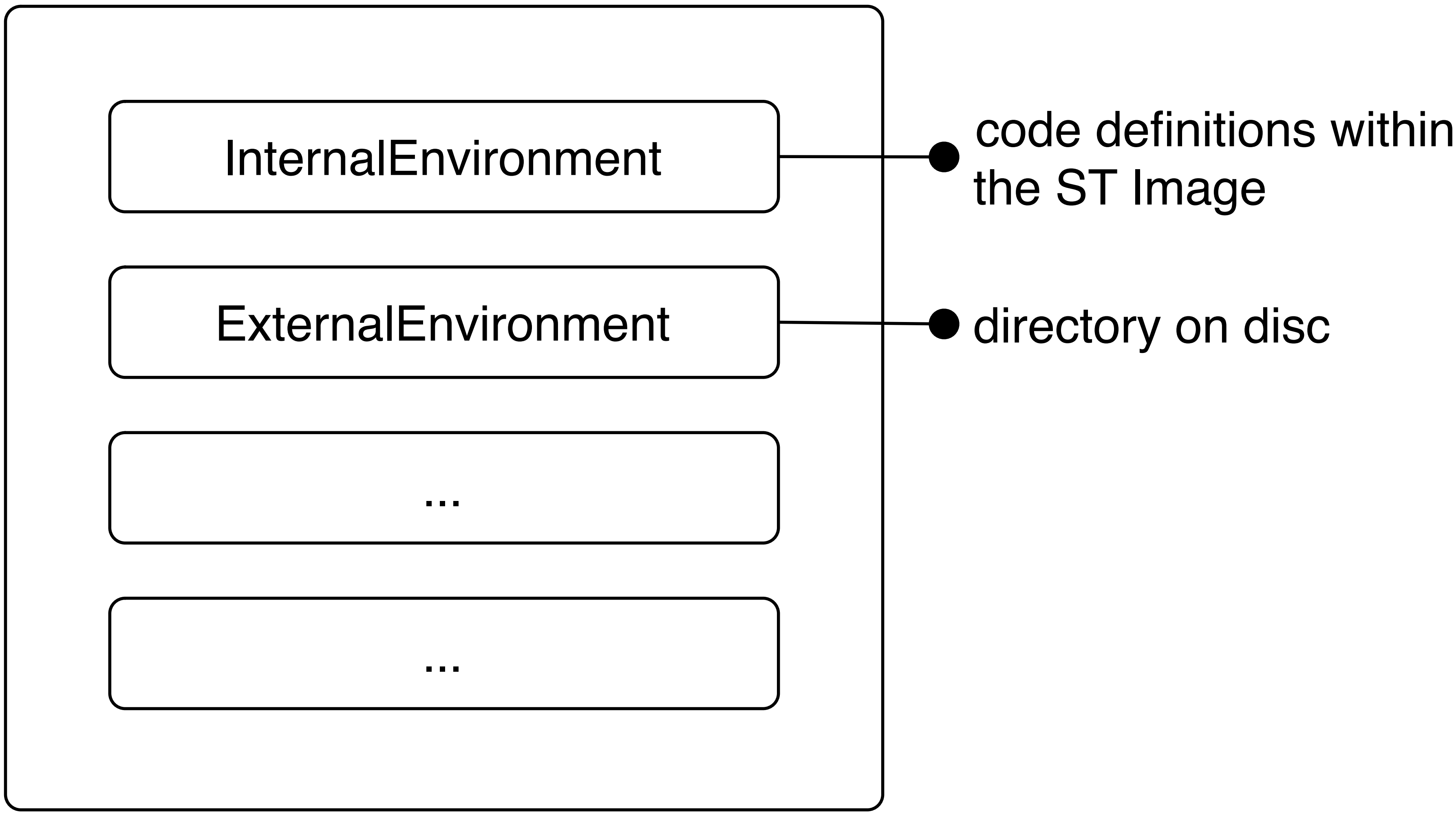
Traits Preprocessor



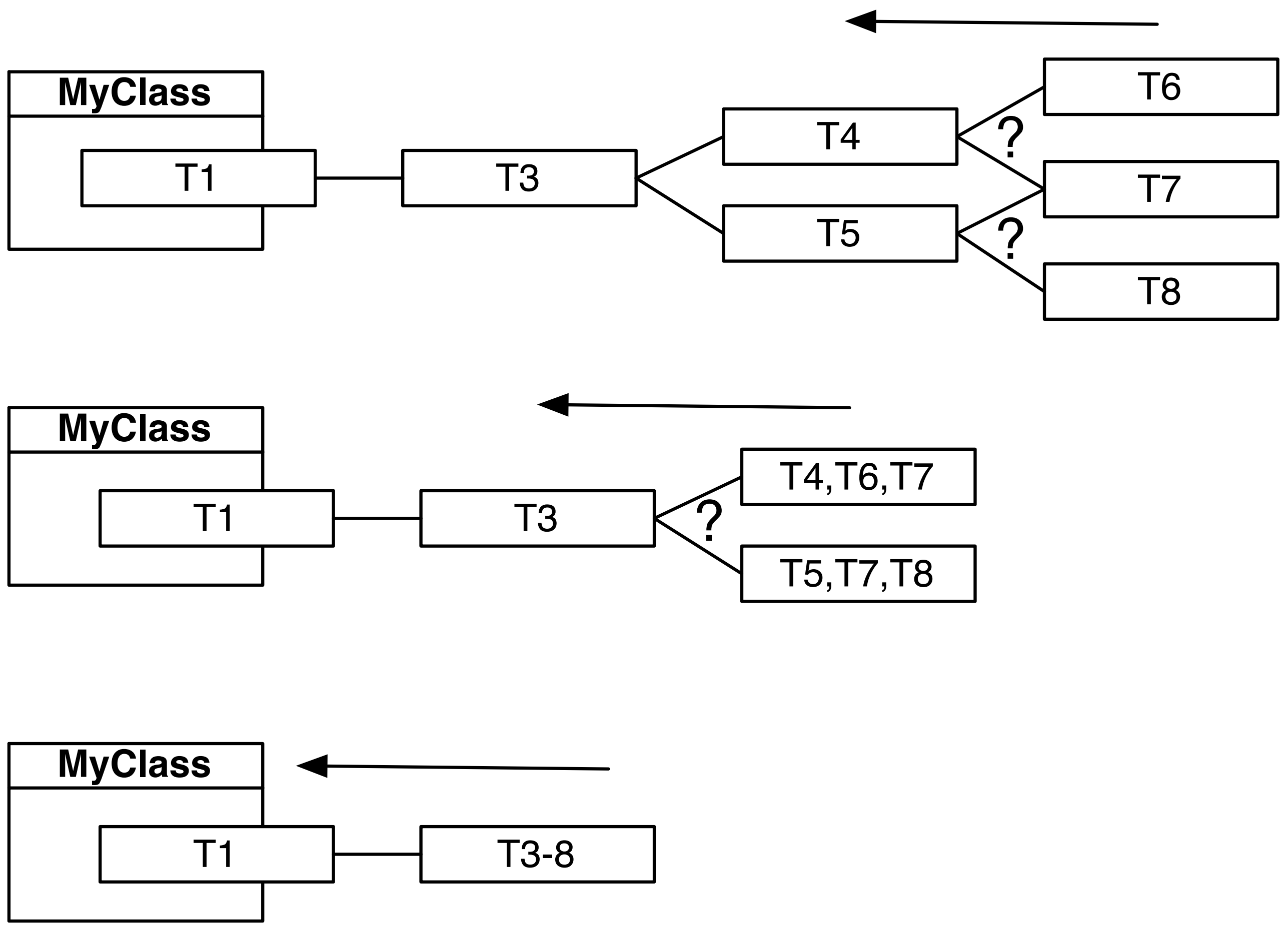
Parser Framework



Environment (singleton)



Trait Flattening Logic (1)



...

Trait Flattening Logic (2)