Pitfalls of C# Generics and Their Solution Using Concepts

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Mechanisms of Generic Programming

1. **Unconstrained C++ Templates.**

2. **Mechanisms Based on Explicit Constraints:**
   C# and Java generics, Haskell type classes, ML signatures, Scala traits, etc.
1. **Unconstrained C++ Templates.**
   - flexibility;
   - expressiveness;
   - late stage of error detection;
   - unclear error messages.

2. **Mechanisms Based on Explicit Constraints:**
   C# and Java generics, Haskell type classes, ML signatures, Scala traits, etc.
Mechanisms of Generic Programming

1. Unconstrained C++ Templates.
   - flexibility;
   - expressiveness;
   - late stage of error detection;
   - unclear error messages.

2. Mechanisms Based on Explicit Constraints: C# and Java generics, Haskell type classes, ML signatures, Scala traits, etc.
   - early stage of error detection;
   - error messages in terms of constraints;
   - (in most cases) weaker expressiveness.
Explicit-Constraints-Based Mechanisms

How do they differ?

1. Support different kinds of constraints/requirements (function signatures, associated types, same-type constraints, etc.)
2. Provide different features (retroactive modeling, multi-type constraints, constraints-propagation, etc.)

- Haskell Type Classes (the most powerful)
- Scala Traits
- ...
- C#/Java Generics (one of the poorest)
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- C#/Java Generics (one of the poorest)
- C++ Concepts
A term “concept” comes from the Standard Template Library (STL).

C++ Concepts as a new language construct:

- are underway in C++ community since 2000 (Bjarne Bjarne, Gabriel Dos Reis, Douglas Gregor, Jaakko Järvi and others);
- in respect to expressive power are comparable with Haskell type classes;
- are as effective as templates;
- do not suffer from templates diseases;
- are treated as a possible substitution of unconstrained templates;
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- are as effective as templates;
- do not suffer from templates diseases;
- are treated as a possible substitution of unconstrained templates;
- are still not included in C++.
To introduce concepts into C# language to improve current mechanism of generic programming.

C# Generics (based on F-bounded polymorphism): constraints on type parameters of generic classes and methods are expressed in terms of interfaces and subtyping.

Concepts can be used with interfaces simultaneously.
Why C#?

There are two aspects:

1. **A Design.** The design of concepts proposed is applicable to C#, Java and any .NET language with GP mechanism based on *F-bounded polymorphism*.

2. **An Implementation.** The method of concepts translation is strongly oriented to .NET Framework.

C# is suitable both for syntax demonstration and implementation.
Concept Sample 1

Concept

- represents some abstraction;
- defines a named set of requirements on type parameters.

Monoid example

```csharp
concept CMonoid[T]
{
    T bin0p(T x, T y);
    T ident;
}

static T Accumulate<T>(T[] values)
where CMonoid[T] using cM
{
    T result = cM.ident;
    foreach (T val in values)
    {
        result = cM.bin0p(result, val);
    }
    return result;
}
```

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Monoid example in C#:

```csharp
interface IMonoid<T>
    where T : IMonoid<T>
{
    T binOp(T other);
}

static T Accumulate<T>(
    T[] values, T ident
) where T : IMonoid<T>
{
    T result = ident;
    foreach (T val in values)
        result = result.binOp(val);
    return result;
}
```
C# Pitfalls

- lack of retroactive interface implementation;
- recursive constraints;
- constraints-compatibility problem;
- multi-type constraints problem;
- constraints duplication;
- verbose type parameters.
Generics

```csharp
class HashSet<T>  
    (IEqualityComparer<T>)

static HashSet<T> GetUnion<T>(
    HashSet<T> s1,
    HashSet<T> s2
)
{
    var us = new HashSet<T>(
        s1, s1.Comparer
    );
    us.UnionWith(s2);
    return us;
}

// GetUnion(s1, s2)
// != GetUnion(s2, s1)
```

Generics with Concepts

```csharp
class HashSet<T>
    where CEqualityComparable{T}

static HashSet<T> GetUnion<T>(
    HashSet<T> s1,
    HashSet<T> s2
)
{
    var us = new HashSet<T>(
        s1
    );
    us.UnionWith(s2);
    return us;
}

// GetUnion(s1, s2)
// == GetUnion(s2, s1)
```
The Sketch of Translation

Owing to the properties of the .NET Framework:

1. A resultant code of translation is **generic**.
2. Meta-information is preserved via **attributes**.

- **Concept** — abstract generic class. Type parameters and nested concept requirements — type parameters of this generic class.
- **Generic class** — generic class with extra type parameters for concept requirements.
- **Model** — class, a subtype of the corresponding abstract generic class of concept.
- **Instantiation of generic class** — instantiation of the corresponding generic class with extra type parameters.
The Advantages of Translation

1. **Lowering the run-time expenses** due to passing concepts as *types* (in contrast to G concepts [4] and Scala “concept pattern” [3]).

2. **Modularity** can be provided due to preserving full type information and meta-information.
## Conclusion and Future Work

Comparison of “Concepts” Designs Under Garcia et. al. [1]

<table>
<thead>
<tr>
<th>Feature</th>
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<th>C#ext</th>
<th>JGI</th>
<th>Scl</th>
<th>C#cpt</th>
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<td>+</td>
<td>+²</td>
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</tr>
</tbody>
</table>

“C#ext” means C# with associated types [2].
“Scl” means Scala [3].
“C#ext” means C# with concepts.

1 partially supported via “concept pattern”
2 supported via “concept pattern”
3 supported via “concept pattern” and implicits
4 partially supported by prioritized overlapping implicits
Future Work

- Formalization of translation.
- Implementation of C# compiler for restricted language.
- Concept syntax “approbation”.
References


Monoid Concept

Concept CMonoid[T]
{
    T binOp(T x, T y);
    T ident;
}

Abstract class CMonoid<T>
{
    public abstract T binOp(T x, T y);
    public abstract T ident { get; }
}

Generic Method

Static T Accumulate<T>(
    T[] values
) where CMonoid[T]
{
    ... 
}

Static T Accumulate<T, CMonoid_T>(
    T[] values
) where CMonoid_T : CMonoid<T>
{
    ... 
}