The Curiously Recurring Template Pattern: History and Application in Orthogonal Expansions

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Table of contents

1 Historical Context

The Curiously Recurring Template Pattern (CRTP) emerged from multiple sources in the mid-1990s. While its theoretical foundations were established in 1989 under the academic term "F-bound polymorphism", the pattern received its memorable name from Jim Coplien in 1995 through his "Column Without a Name" in C++ Report — an amusing irony given the pattern's previous nameless state.

In a parallel development, Microsoft developers working on the Active Template Library (ATL) independently discovered the pattern in 1995. Jan Falkin's accidental derivation of a base class from a derived class led to what would become a cornerstone of both ATL and the Windows Template Library (WTL).

2 Technical Structure

The pattern's fundamental form involves a class inheriting from a templated base class using itself as the template parameter:

$$\text{class Derived extends Base<Derived>} \tag{1}$$

3 Application to Orthogonal Expansions

In the context of orthogonal function expansions, CRTP manifests in a particularly elegant way. Consider the implementation:

```
public class LegendrePolynomialExpansion extends OrthogonalExpansion<Real,
Real, LegendrePolynomialExpansion, LegendrePolynomialSequence>
```

This structure enables the expansion class to serve as both:

- The concrete implementation of the expansion
- The function type parameter in its own definition

4 Theoretical Significance

The pattern's importance extends beyond mere implementation details:

1. It enables static polymorphism without virtual function overhead
2. Provides compile-time type safety
3. Allows base classes to access derived class members during compilation
4. Facilitates template metaprogramming techniques

5 Historical Impact

The pattern's discovery challenged conventional wisdom about inheritance and template instantiation. Many developers initially doubted such recursive template instantiation would compile — a skepticism so widespread it contributed to the pattern's "Curious" designation in its name.

This skepticism reflects a deeper truth about software patterns: sometimes the most powerful idioms are those that seem to defy our intuitive understanding of programming language mechanics.

6 Modern Applications

CRTP has become fundamental in modern C++ libraries, particularly in:

- Windows Template Library (WTL)
- Active Template Library (ATL)
- Various numerical computing frameworks

Its adoption in Java through generics demonstrates its language-transcending utility, particularly in mathematical and scientific computing applications like orthogonal function expansions.