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Reply to: Herb Sutter
Microsoft Corp.
1 Microsoft Way
Redmond WA USA 98052-6399
Fax: +1-928-438-4456
Email: hsutter@gotw.ca

Proposed Addition to C++: Typedef Templates

With comments and examples from Dave Abrahams, Peter Dimov, John Spicer, and Daveed Vandevoorde.

1. The Problem, and Current Workarounds

We would like to allow the programmer to create a synonym for a template where some, but not all, actual template arguments are fixed.

The problem is important because such a facility would make it possible to create more easily usable template libraries. For example, consider a template like this:

```
template<typename T1,  
        typename T2,  
        typename T3 = int  
        typename T4 = string>  
class C { /*...*/ };
```

Today, default template arguments already enable programmers to use the template more naturally (and less tediously) as just:

```
C<bool, short> x; // synonym for C<bool, short, int, string>
```

Alternatively, we can also use typedefs to create a synonym for another type, including a synonym for a template specialization with all actual template arguments specified:

```
typedef C<bool, short, long, wstring> Phil;  
Phil p;
```

It is not, however, possible in general to use default arguments or typedefs to create a more usable name for a template where some, but not all, actual template arguments are fixed. The ability to create a synonym which specifies only some template arguments while allowing others to still vary would be useful and help to create more naturally usable names in libraries.

In existing practice, including in the standard library, type names nested inside helper templates are used to work around this problem in some cases. The following is one example of this workaround; one drawback is the need to write “: :Type”, and another is that this workaround does not work for all cases.

```
template< typename T >
struct SharedPtr
{
    typedef Loki::SmartPtr
        <
            T,                // note, T still varies
            RefCounted,      // but everything else is fixed
            NoChecking,
            false,
            PointsToOneObject,
            SingleThreaded,
            SimplePointer<T> // note, T can be used as here
        >
        Type;
};
```

```
SharedPtr<int>::Type p; // sample usage, "::Type" is ugly
```

What we'd really like to be able to do is simply this:

```
template< typename T >
typedef Loki::SmartPtr
    <
        T,                // note, T still varies
        RefCounted,      // but everything else is fixed
        NoChecking,
        false,
        PointsToOneObject,
        SingleThreaded,
        SimplePointer<T> // note, T can be used as here
    >
    SharedPtr;
```

```
SharedPtr<int> p; // sample usage, "::Type" is ugly
```

For another example, the standard library's rebind helpers fall into this category:

```
template<typename T> class allocator { //...
    template<typename U>
    struct rebind { typedef allocator<U> other; };
};
```

```
allocator<T>::rebind<U>::other x; // sample usage
```

What we'd really like to be able to do is simply this:

```
template<typename T> class allocator { //...
    template<typename U>
    typedef allocator<U> rebind;
};
```

```
allocator<T>::rebind<U> x;           // sample usage
```

In fact, the standard itself says: “The template class member `rebind` [...] *is effectively a template typedef*: if the name `Allocator` is bound to `SomeAllocator<T>`, then `Allocator::rebind<U>::other` is the same type as `SomeAllocator<U>`.” [emphasis mine]

These workarounds are ugly, and do not work for all cases (e.g., the workaround can’t match a template template parameter).

This proposal fits into the categories of:

- improve support for library building
- improve support for generic programming
- remove embarrassments (inasmuch as the absence of typedef templates is a known weakness in the language)

2. The Proposal

2.1 Basic Cases

A typedef introduces a synonym, rather than a complete new type. Similarly, a typedef template introduces a parameterized synonym, not a complete new type. One purpose for allowing templatization of a typedef is to introduce a simplified synonym for an existing template where some but not all template arguments are fixed. For example:

```
template<typename A, typename B> class X { /* ... */ };
template<typename T> typedef X<T,int> Xi;
Xi<double> Ddi; // equivalent to X<double,int>
```

A typedef template can be modeled like a partial specialization, with the definition being the primary class template. The syntax naturally follows the existing syntax for function and class templates:

```
void f( int ); // function
template<typename T> void f( T );
// function template, usage f<int>

class X { }; // class
template<typename T> class X { };
// class template, usage X<int>

typedef map<string, Employee> EmployeeRegistry; // typedef
template<typename T> typedef map<string, T> Registry;
// typedef template, usage Registry<Employee>
```

It uses the same rules as function and class templates for dependent names (including the use of `typename` within the typedef template for dependent type names), non-type parameters, and template template parameters.

Here’s an example that comes up in many class templates, particularly in policy-based design (heavily used in Loki) where there are many template parameters and we currently can’t express a typedef name that fixes some but not all of the types. In this example, I cite Loki’s `SmartPtr`, which is very flexible

because it allows customization via several policy template parameters. Unfortunately, having so many template parameters also makes it harder to use. There are several common uses of Loki's SmartPtr with particular template parameters fixed that it would be useful to be able to invoke more simply via a synonym. For example:

```
template< typename T >
typedef Loki::SmartPtr
    <
        T,                // note, T still varies
        RefCounted,      // but everything else is fixed
        NoChecking,
        false,
        PointsToOneObject,
        SingleThreaded,
        SimplePointer<T> // note, T can be used as here
    >
    SharedPtr;

template< typename T >
typedef Loki::SmartPtr
    <
        T,
        RefCounted,
        NoChecking,
        false,
        PointsToArray,
        SingleThreaded,
        SimplePointer<T>
    >
    SharedArray;

template< typename T >
typedef Loki::SmartPtr
    <
        T,
        NonCopyable,
        NoChecking,
        false,
        PointsToOneObject,
        SingleThreaded,
        SimplePointer<T>
    >
    ScopedPtr;

template< typename T >
typedef Loki::SmartPtr
    <
        T,
        NonCopyable,
        NoChecking,
```

```
    false,  
    PointsToArray,  
    SingleThreaded,  
    SimplePointer<T>  
>  
ScopedArray;
```

2.2 Specialization

Consider the following typedef template:

```
template<typename A, typename B> class X { /* ... */ };  
template<typename T> typedef X<T,int> Xi;
```

To specialize the typedef template, use the same syntax as when specializing class and function templates:

```
// specialization for string  
template<> typedef UnrelatedType Xi<string>;  
  
...  
Xi<double> Ddi;    // uses base template  
Xi<string> Ssi;   // uses specialization
```

To partially specialize the typedef template, use the same syntax as when partially specializing class and function templates — the only trick is to remember where the template argument list goes, namely right after the name being specialized. For class templates, the standard says: “For partial specializations, the template argument list is explicitly written immediately following the class template name.” So, for partial specializations of typedef templates, the template argument list is explicitly written immediately following the typedef template name:

```
// partial specialization for pointers  
template<typename T> typedef AnotherUnrelatedType<T> Xi<T*>;  
  
...  
Xi<double> Ddi;    // uses base template  
Xi<int*> Ipi;      // uses partial specialization
```

Here are additional motivating cases for allowing specialization, provided by Peter Dimov:

```
template<int> typedef int int_exact;  
template<> typedef char int_exact<8>;  
template<> typedef short int_exact<16>;  
// ...  
  
template<class T> typedef T remove_const;  
template<class T> typedef T remove_const<T const>;
```

It has been observed that we have to choose between allowing specialization and allowing deduction. John Spicer notes that the current workaround for template typedefs does not allow deduction either, so the most straightforward solution would be to disallow deduction and allow specialization.

2.3 Same Declarations

A declaration having a parameter whose type is expressed in terms of a typedef template is identical to the same declaration with the parameter expressed in terms of the type for which the typedef template is a synonym. A motivating example follows, provided by Peter Dimov:

```
template<class T, class P> class smart_ptr;
template<class T> typedef smart_ptr<T, SharedPolicy> shared_ptr;

template<class T> void f(smart_ptr<T, SharedPolicy>);
template<class T> void f(shared_ptr<T>);
```

2.4 Matching template template parameters

A typedef template can be used as an argument to a template template parameter, as in the following example:

```
template<template<class> class X> class Y {};
```

```
template<class, class> class Z {};
```

```
template<class T> typedef Z<T, T> A;
```

```
Y<A> a; // uses adapted Z
```

3. Interactions and Implementability

3.1 Interactions

The proposed feature is intended to be a natural application of existing template syntax to the existing typedef keyword. Interactions with the rest of the language are limited because typedef templates do not create a new type or extend the type system in any way; they only create synonyms for other types.

This is not a one-off or special-purpose feature. Consider the example in §2.2, and the ease of use of letting the programmer write:

```
SharedPtr<int> p;
SharedArray<int> a;
```

instead of:

```
SharedPtr<int>::Type p;
SharedArray<int>::Type a;
```

or, worse still:

```
SmartPtr<int, RefCounted, NoChecking, false,  
        PointsToOneObject, SingleThreaded,  
        SimplePointer<int> > p;  
  
SmartPtr<int, RefCounted, NoChecking, false,  
        PointsToArray, SingleThreaded,  
        SimplePointer<int> > a;
```

The naturalness and ease of use of the first case is possible only with typedef templates, and will make advanced C++ libraries more accessible to programmers.

A typedef template can be used as a template template argument if it otherwise matches the rules for such an argument. When so used, however, it is just a “syntactic sugar” synonym. Because typedef templates can be specialized, at the point of instantiation the typedef template specialization (if any) is found and used, and if it refers to another template then that template’s specialization (if any) is also found and used.

It is recommended that a typedef template parameter be deducible as in this example:

```
template<typename T>  
typedef T MyT;  
  
template<typename T>  
void f( MyT<T> );  
  
void g() {  
    MyT<int> val = 42;  
    f( val );           // succeeds, T is deduced to be int  
    f( 42 );           // fails, T can't be deduced  
}
```

3.2 Implementability

A sample implementation that allows the basic usages, but not specialization or deduction, was created as an unshipped extension within the Microsoft compiler with little difficulty. The work to add specialization and deduction is not expected to be difficult, but of course that won’t be known for sure until it’s done.