Template Variations

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Template Variations (folder 1)

A template can receive several arguments:

```
template <typename T1, typename T2>
struct pair {
    T1 first;
    T2 second;
};
pair<string,int> func() {return {"hi",2};}
int main()  {
    pair<string,int> a {"hello", 3};
    auto b = func();
}
```

Template Variations (folder 1)

A template can receive constant integral arguments:

```
template<typename T, int Size>
class array { T m_values[Size];
public:
    // operator[] , operator<<
    // static size constant ...
};
array<char,1024> arr1;
// vector<char> arr1(1024); // dynamic
// char arr1[1024];         // static
```

Template Specialization

Template function specialization (folder 2)

Example application:

- General swap – uses operator=.
- Specific swap for a "Buffer" class –
  swaps the size and the pointer (see folder 2).

Template class specialization (folder 3)

```
template <typename T> class Test {
  public:  Test()  {     cout << "General";  }
};

template <> class Test <int> {
  public: Test()    {     cout << "Specialized";    }
};

int main()  {
    Test<int> a;       // Specialized
    Test<char> b;   // General
    Test<float> c;   // General
}
```

Template class specialization (folder 3)

Example application:

- We have a general vector<T>
- We create a specific vector<bool> to reduce memory space – save 8 bools in one char.
- We use the *Proxy design pattern*.
- See folder 3.

Template class specialization (folder 4)

Example application:

- We have a template function that should only work for numeric arguments.
- We create a *template* to tell us whether a type is numeric.
- We create a compiler error using the static_assert keyword.
- See folder 4
  - More examples:

    https://en.cppreference.com/w/cpp/header/type_traits

Template class specialization (folder 5)

Example application:

- We have a template function whose return-type should change based on the template type.
- We create a *class* that keeps a field with the required return type.
- We get the return type with the decltype keyword.
- See folder 5.

Template Meta-Programming

Template Meta-Programming

```
// primary template computes 3 to the Nth
template<int N> class Pow3 {  public:
   static const int result =
      3*Pow3<N-1>::result;
};
// full specialization to end recursion
template<> class Pow3<0> {  public:
   static const int result = 1;
};
int main(){
  cout << Pow3<1>::result<<"\n"; //3
  cout << Pow3<5>::result<<"\n"; //243
  return 0;
}
```

Template Meta-Programming (folder 6)

Goal: Numerically calculate and plot the n-th derivative of an arbitrary function.

Steps:

1) rgb.hpp – class for creating a ppm picture file (see week 7), and plotting a ”function-like object” (=functor).
2) functors_demo.cpp – demonstrates plotting various functors and lambda expressions.
3) derivative.hpp – the derivative template.
4) animate_demo.cpp – function animation.

Summary: Polymorphism vs. Templates

- Templates compilation time is much longer than using inheritance.
- Using templates enlarges the code size.
- Compilation errors can be very confusing.

- Templates running time is much faster than using inheritance.
- Combined with compiler optimizations, templates can reduce runtime overhead to zero.

Longer compilation time is cool (from xkcd):