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SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

# Advanced Programming

## CS205

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# Class Templates



# Review: Function Templates

- A function template is not a type, or a function, or any other entity.
- No code is generated from a source file that contains only template definitions.
- The template arguments must be determined, then the compiler can generate an actual function
- **"Function templates" vs "template functions".**

```
template<typename T>
T sum(T x, T y)
{
    cout << "The input type is " << typeid(T).name() << endl;
    return x + y;
}
```

```
// instantiates sum<double>(double, double)
template double sum<double>(double, double);
// instantiates sum<char>(char, char), template argument deduced
template char sum<>(char, char);
// instantiates sum<int>(int, int), template argument deduced
template int sum(int, int);
```



# Review: Function Templates

- Implicit instantiation occurs when a function template is not explicitly instantiated.

```
template<typename T>
T sum(T x, T y)
{
    cout << "The input type is " << typeid(T).name() << endl;
    return x + y;
}
```

```
// Implicitly instantiates sum<int>(int, int)
cout << "sum = " << sum<int>(2.2f, 3.0f) << endl;
// Implicitly instantiates sum<float>(float, float)
cout << "sum = " << sum(2.2f, 3.0f) << endl;
```



# Different Classes for Different Type Matrices

- Matrix with **int** elements, Matrix with **float** elements

```
// Class IntMat
class IntMat
{
    size_t rows;
    size_t cols;
    int * data;
public:
    IntMat(size_t rows, size_t cols):
        rows(rows), cols(cols)
    {
        data = new int[rows * cols]{};
    }
    ~IntMat()
    {
        delete [] data;
    }
    IntMat(const IntMat&) = delete;
    IntMat& operator=(const IntMat&) = delete;
    int getElement(size_t r, size_t c);
    bool setElement(size_t r, size_t c, int value);
};
```

```
// Class FloatMat
class FloatMat
{
    size_t rows;
    size_t cols;
    float * data;
public:
    FloatMat(size_t rows, size_t cols):
        rows(rows), cols(cols)
    {
        data = new float[rows * cols]{};
    }
    ~FloatMat()
    {
        delete [] data;
    }
    FloatMat(const FloatMat&) = delete;
    FloatMat& operator=(const FloatMat&) = delete;
    float getElement(size_t r, size_t c);
    bool setElement(size_t r, size_t c, float value);
};
```



# Class Templates

- A class template defines a family of classes.
- Class template instantiation.

```
template<typename T>
class Mat
{
    size_t rows;
    size_t cols;
    T * data;
public:
    Mat(size_t rows, size_t cols): rows(rows), cols(cols)
    {
        data = new T[rows * cols]{};
    }
    ~Mat()
    {
        delete [] data;
    }
    T getElement(size_t r, size_t c);
    bool setElement(size_t r, size_t c, T value);
};
```

```
// Explicitly instantiate
template class Mat<int>;
```

mattemplate.cpp



# Class Template

- How to handle different combinations?

```
Mat<int> imat(3,4);
```

```
Mat<float> fmat(3,4);
```

```
Mat<double> dmat = imat + fmat; //?
```



# Matrix type in OpenCV

```
class CV_EXPORTS Mat
```

```
{
```

```
public:
```

```
    /** @brief Returns the depth of a matrix element.
```

The method returns the identifier of the matrix element depth (the type of the matrix element). For example, for a 16-bit signed element array, the method returns CV\_16S. The list of matrix types contains the following values:

- CV\_8U - 8-bit unsigned integers ( 0..255 )
- CV\_8S - 8-bit signed integers ( -128..127 )
- CV\_16U - 16-bit unsigned integers ( 0..65535 )
- CV\_16S - 16-bit signed integers ( -32768..32767 )
- CV\_32S - 32-bit signed integers ( -2147483648..2147483647 )
- CV\_32F - 32-bit floating-point numbers ( -FLT\_MAX..FLT\_MAX, INF, NAN )
- CV\_64F - 64-bit floating-point numbers ( -DBL\_MAX..DBL\_MAX, INF, NAN )

```
    */
```

```
    int depth() const;
```

```
    /*! includes several bit-fields:
```

- the magic signature
- continuity flag
- depth
- number of channels

```
    */
```

```
    int flags;
```

```
    ...
```

```
}
```

```
#define CV_CN_MAX 512
```

```
#define CV_CN_SHIFT 3
```

```
#define CV_DEPTH_MAX (1 << CV_CN_SHIFT)
```

```
#define CV_8U 0
```

```
#define CV_8S 1
```

```
#define CV_16U 2
```

```
#define CV_16S 3
```

```
#define CV_32S 4
```

```
#define CV_32F 5
```

```
#define CV_64F 6
```

```
#define CV_16F 7
```

```
#define CV_MAT_DEPTH_MASK (CV_DEPTH_MAX - 1)
```

```
#define CV_MAT_DEPTH(flags) ((flags) & CV_MAT_DEPTH_MASK)
```

```
inline
```

```
int Mat::depth() const
```

```
{
```

```
    return CV_MAT_DEPTH(flags);
```

```
}
```





# Matrix type in OpenCV

modules/imgproc/src/thresh.cpp

```
if (srcStripe.depth() == CV_8U)
{
    thresh_8u( srcStripe, dstStripe, (uchar)thresh, (uchar)maxval, thresholdType );
}
else if( srcStripe.depth() == CV_16S )
{
    thresh_16s( srcStripe, dstStripe, (short)thresh, (short)maxval, thresholdType );
}
else if( srcStripe.depth() == CV_16U )
{
    thresh_16u( srcStripe, dstStripe, (ushort)thresh, (ushort)maxval, thresholdType );
}
else if( srcStripe.depth() == CV_32F )
{
    thresh_32f( srcStripe, dstStripe, (float)thresh, (float)maxval, thresholdType );
}
else if( srcStripe.depth() == CV_64F )
{
    thresh_64f(srcStripe, dstStripe, thresh, maxval, thresholdType);
}
```



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# Template Non-Type Parameters



# Non-Type Parameters

- To declare a template

`template` < parameter-`list` > declaration

- The parameters can be
  - type template parameters
  - template template parameters
  - non-type template parameters
    - ✓ integral types
    - ✓ floating-point type
    - ✓ pointer types
    - ✓ lvalue reference types
    - ✓ ...

```
vector<int> vec1;  
vector<int, 16> vec2;
```



# Non-Type Parameters

- If we want to create a static matrix (no dynamic memory allocation inside)

```
template<typename T, size_t rows, size_t cols>
class Mat
{
    T data[rows][cols];
public:
    Mat(){}
    T getElement(size_t r, size_t c);
    bool setElement(size_t r, size_t c, T value);
};
```

```
int r=3, c=3;
Mat<int> vec1(r, c);
Mat<int> vec2(3, 3);

Mat<int, 3, 3> vec3;
```



# Template in OpenCV

```
template<typename _Tp, int m, int n> class Matx
{
public:
    enum {
        rows      = m,
        cols       = n,
        channels     = rows*cols,
#ifdef OPENCV_TRAITS_ENABLE_DEPRECATED
        depth      = traits::Type<_Tp>::value,
        type       = CV_MAKETYPE(depth, channels),
#endif
        shortdim   = (m < n ? m : n)
    };
};
```

```
typedef Matx<float, 1, 2> Matx12f;
typedef Matx<double, 1, 2> Matx12d;
typedef Matx<float, 1, 3> Matx13f;
typedef Matx<double, 1, 3> Matx13d;
typedef Matx<float, 1, 4> Matx14f;
typedef Matx<double, 1, 4> Matx14d;
typedef Matx<float, 1, 6> Matx16f;
typedef Matx<double, 1, 6> Matx16d;
```



# Template in OpenCV

```
template<typename _Tp, int cn> class Vec : public Matx<_Tp, cn, 1>
{
public:
    typedef _Tp value_type;
    enum {
        channels = cn,
#ifdef OPENCV_TRAITS_ENABLE_DEPRECATED
        depth     = Matx<_Tp, cn, 1>::depth,
        type      = CV_MAKETYPE(depth, channels),
#endif
        _dummy_enum_finalizer = 0
    };
};
```

```
typedef Vec<uchar, 2> Vec2b;
typedef Vec<uchar, 3> Vec3b;
typedef Vec<uchar, 4> Vec4b;
```

```
typedef Vec<short, 2> Vec2s;
typedef Vec<short, 3> Vec3s;
typedef Vec<short, 4> Vec4s;
```

```
typedef Vec<ushort, 2> Vec2w;
typedef Vec<ushort, 3> Vec3w;
typedef Vec<ushort, 4> Vec4w;
```

```
typedef Vec<int, 2> Vec2i;
typedef Vec<int, 3> Vec3i;
typedef Vec<int, 4> Vec4i;
```



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# Class Template Specialization



# Class template specialization

- The class template can be for most types
- But we want to save memory for type **bool** (1 byte or 1 bit).

```
template<typename T>
class MyVector
{
    size_t length;
    T * data;
public:
    MyVector(size_t length): length(length)
    { data = new T[length]{}; }
    ~MyVector()
    { delete [] data; }
    MyVector(const MyVector&) = delete;
    MyVector& operator=(const MyVector&) = delete;
    T getElement(size_t index);
    bool setElement(size_t index, T value);
};
```

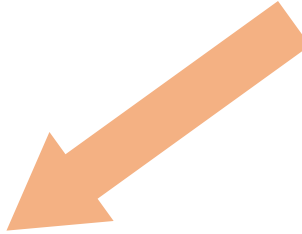




# Class template specialization

```
template<>
class MyVector<bool>
{
    size_t length;
    unsigned char * data;
public:
    MyVector(size_t length): length(length)
    {
        int num_bytes = (length - 1) / 8 + 1;
        data = new unsigned char[num_bytes]{};
    }
    ~MyVector()
    {
        delete [] data;
    }
    MyVector(const MyVector&) = delete;
    MyVector& operator=(const MyVector&) = delete;
    bool getElement(size_t index);
    bool setElement(size_t index, bool value);
};
```

- Specialize MyVector for **bool**



specialization.cpp



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# std classes



# std::basic\_string

- Store and manipulate sequences of char-like objects.

Defined in header `<string>`

Type	Definition
<code>std::string</code>	<code>std::basic_string&lt;char&gt;</code>
<code>std::wstring</code>	<code>std::basic_string&lt;wchar_t&gt;</code>
<code>std::u8string</code> (C++20)	<code>std::basic_string&lt;char8_t&gt;</code>
<code>std::u16string</code> (C++11)	<code>std::basic_string&lt;char16_t&gt;</code>
<code>std::u32string</code> (C++11)	<code>std::basic_string&lt;char32_t&gt;</code>
<code>std::pmr::string</code> (C++17)	<code>std::pmr::basic_string&lt;char&gt;</code>
<code>std::pmr::wstring</code> (C++17)	<code>std::pmr::basic_string&lt;wchar_t&gt;</code>
<code>std::pmr::u8string</code> (C++20)	<code>std::pmr::basic_string&lt;char8_t&gt;</code>
<code>std::pmr::u16string</code> (C++17)	<code>std::pmr::basic_string&lt;char16_t&gt;</code>
<code>std::pmr::u32string</code> (C++17)	<code>std::pmr::basic_string&lt;char32_t&gt;</code>



# std::array

- a container that encapsulates **fixed** size arrays.

```
template<  
    class T,  
    std::size_t N  
> struct array;
```

```
std::array<int, 3> a2 = {1, 2, 3};
```

\*Keyword: `typename/class`, `class/struct`



# Some other templates

```
template<
    class T,
    class Allocator = std::allocator<T>
> class vector;
```

```
template<
    class T,
    class Allocator = std::allocator<T>
> class list;
```

```
template<
    class Key,
    class Compare = std::less<Key>,
    class Allocator = std::allocator<Key>
> class set;
```

```
template<
    class Key,
    class T,
    class Compare = std::less<Key>,
    class Allocator = std::allocator<std::pair<const Key, T> >
> class map;
```

```
template<
    class T,
    class Container = std::deque<T>
> class stack;
```