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C/C++ Program Design

CS205

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Functions

Why functions?

- A compound statement may be needed to execute many times
- You can copy them several times, but ...

```
struct Matrix
{
   int rows;
   int cols;
   float * pData;
};
```

```
Matrix matA;
float maxa = FLT_MIN;
for(int r = 0; r < matA.rows; r++)
   for (int c = 0; c < matA.cols; c++)
   {
      float val = matA.pData[ r * matA.cols + c];
      maxa = ( maxa > val ? maxa : val);
   }
```

nofunction.cpp

Why functions?

- We can put the compound statement into a function

```
float matrix_max(struct Matrix mat)
{
   float max = FLT_MIN;
   for(int r = 0; r < mat.rows; r++)
      for (int c = 0; c < mat.cols; c++)
      {
         float val = mat.pData[ r * mat.cols + c];
         max = ( max > val ? max : val);
      }
   return max;
}
```

```
float maxa = matrix_max(matA);
float maxb = matrix_max(matB);
float maxc = matrix_max(matC);
```

function.cpp

A Question

- If `Matrix::pData` is `NULL` or an invalid value, how to tell the calling function from the called one?
- The pointer should be checked first!

```
float matrix_max(struct Matrix mat)
{
   float max = FLT_MIN;
   for(int r = 0; r < mat.rows; r++)
      for (int c = 0; c < mat.cols; c++)
      {
         float val = mat.pData[ r * mat.cols + c];
         max = ( max > val ? max : val);
      }
   return max;
}
```

Where should a function be? Option 1

```
// draw.cpp
// The function must be defined before it was called

bool drawLine(int x1, int y1, int x2, int y2)
{
   // Source code here
   return true;
}

bool drawRectangle(int x1, int y1, int x2, int y2)
{
   // some calculation here
   drawLine(...);
   drawLine(...);
   drawLine(...);
   drawLine(...);

   return true;
}
```

Where should a function be? Option 2

```
// draw.cpp
// declared first, parameter names can be omitted
bool drawLine(int x1, int y1, int x2, int y2);

bool drawRectangle(int x1, int y1, int x2, int y2)
{
   // some calculation here
   drawLine(...);
   drawLine(...);
   drawLine(...);
   drawLine(...);

   return true;
}
// define it later
bool drawLine(int x1, int y1, int x2, int y2)
{
   // Source code here
   return true;
}
```

Where should a function be? Option 3

```
// draw.h
#ifndef __DRAW_H__
#define __DRAW_H__
bool drawLine(int x1, int y1, int x2, int y2);
bool drawRectangle(int x1, int y1, int x2, int y2);
#endif
```

```
// draw.cpp
#include <draw.h>

bool drawRectangle(int x1, int y1, int x2, int y2)
{
   // some calculation here
   drawLine(...);
   drawLine(...);
   drawLine(...);
   drawLine(...);

   return true;
}
// define it later
bool drawLine(int x1, int y1, int x2, int y2)
```

```
// main.cpp
#include <draw.h>

int main()
{
   // ...
   drawRectangle(10, 20, 50, 100);
   // ...
}
```

How are functions called?

- A call stack can store information about the active functions of a program
  - Store the address the program returns after the function call
  - Store the registers
  - Store the local variables

  - //do some work of the called function

  - Restore the registers
  - Restore the local variables
  - Store the function returned result
  - Jump to the return address

The cost to call a function!

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Function Parameters

Parameters

- The symbolic name for "data" that passes into a function.

Two ways to pass into a function:

- **Pass by value**
- **Pass by reference**

Pass by value: fundamental type

- The parameter is a copy of the original variable

```
int foo(int x)
{   // x is a copy
    x += 10;
    return x;
}

int main()
{
    int num1 = 20;
    int num2 = foo( num1 );

    return 0;
}
```

Will `num1` be changed in foo()?

Pass by value: pointer

- What's the difference?

```
int foo(int * p)
{
   (*p) += 10;
   return *p;
}

int main()
{
   int num1 = 20;
   int * p = &num1;
   int num2 = foo( p );
   return 0;
}
```

It still is passing by value (the address!)

A copy of the address

param-pointer.cpp

Pass by value: structure

- How about structure parameter?

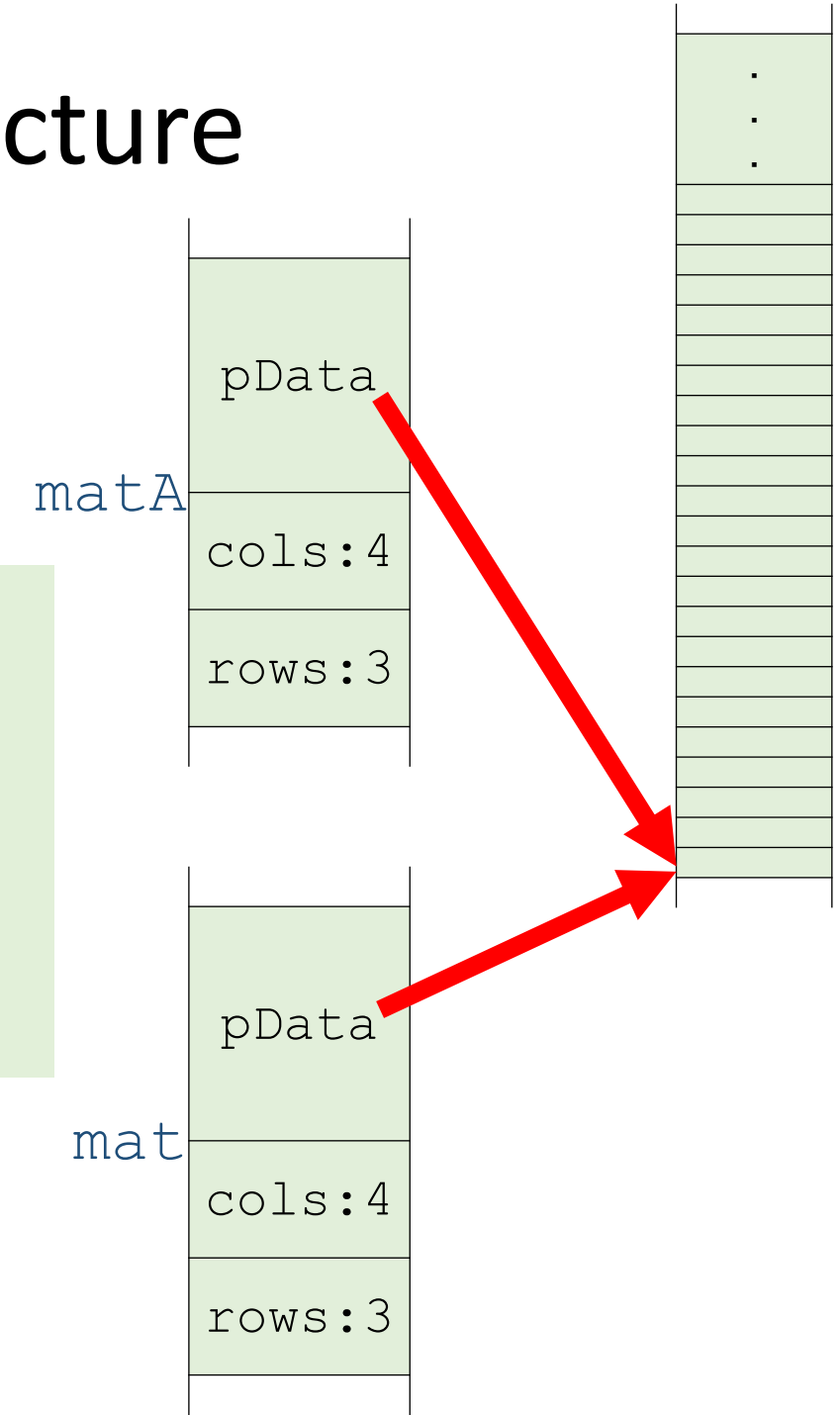
```
struct Matrix
{
   int rows;
   int cols;
   float * pData;
};

float matrix_max(struct Matrix mat)
{
   float max = FLT_MIN;
   for(int r = 0; r < mat.rows; r++)
      for (int c = 0; c < mat.cols; c++)
      {
         float val = mat.pData[ r * mat.cols + c];
         max = ( max > val ? max : val);
      }
   return max;
}
```

Pass by value: structure

```
Matrix matA = {3,4};
matrix_max(matA);
```

```
float matrix_max(struct Matrix mat)
{
   float max = FLT_MIN;
   for(int r = 0; r < mat.rows; r++)
      for (int c = 0; c < mat.cols; c++)
      {
         float val = mat.pData[ r * mat.cols + c];
         max = ( max > val ? max : val);
      }
   return max;
}
```



Pass by value: structure

- If the structure is a huge one, such as 1K bytes.
- A copy will cost 1KB memory, and time consuming to copy it.

?

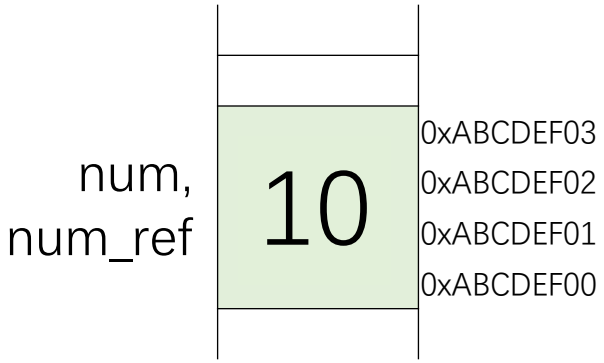
References

References in C++

- References are in C++, not in C.
- A reference is an alias to an already-existing variable/object.

```
int num = 0;
int & num_ref = num;


num_ref = 10;
```

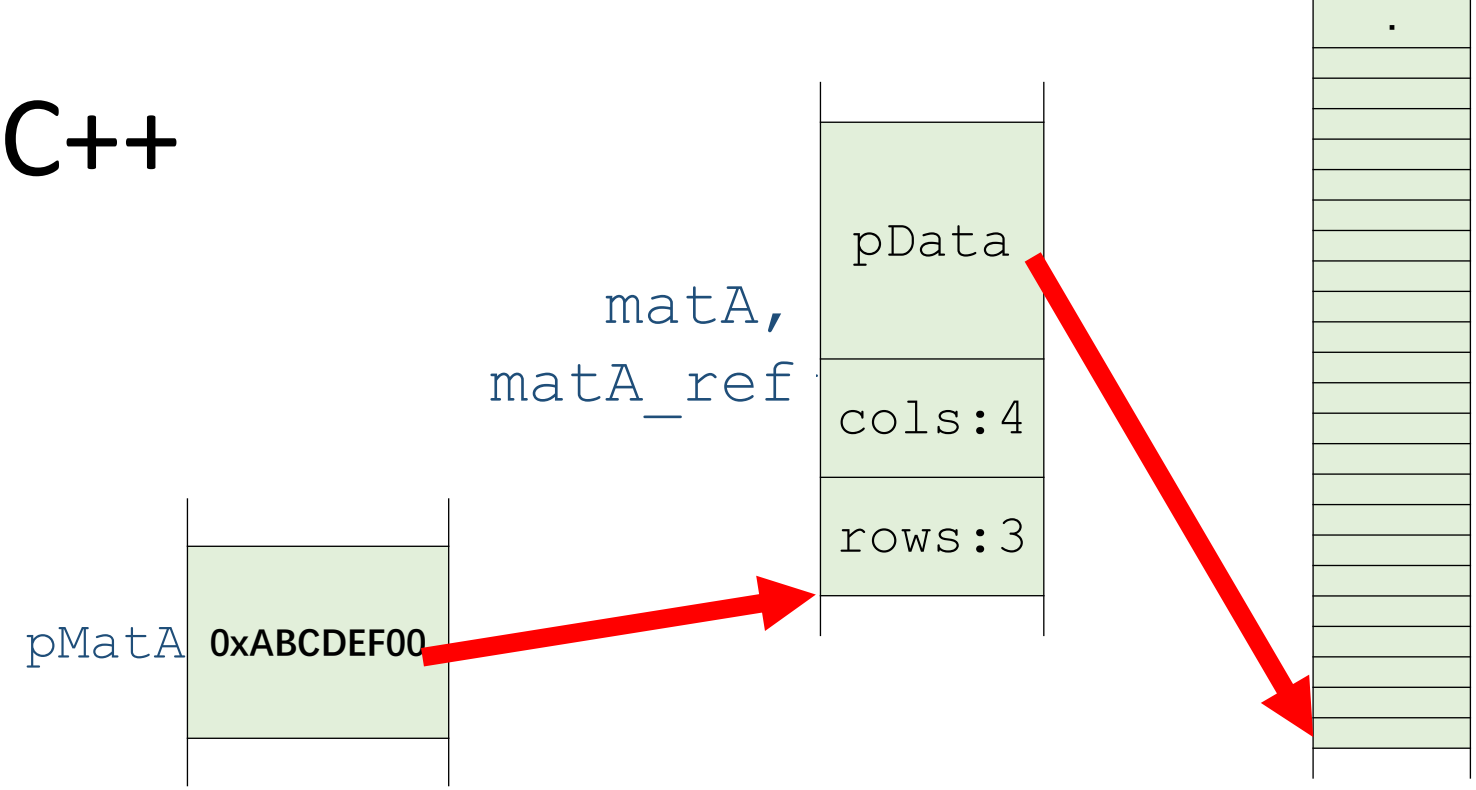


reference.cpp

References in C++

- A reference to an object

```
struct Matrix
{
    int rows;
    int cols;
    float * pData;
};
```




```
Matrix matA = {3,4};
matA.pData = new float[matA.rows * matA.cols]{};

Matrix & matA_ref = matA;

Matrix * pMatA = &matA;
```

References in C++

- A reference must be initialized after its declaration.

```
int & num_ref; // error
Matrix & mat_ref; // error
```

- Reference VS Pointer: References are much safer

Function parameters with a huge structure

- If the huge struct is passed as a function parameter

```
struct PersonInfo
{
   char firstname[256];
   char middlename[256];
   char lastname[256];
   char address[256];
   char nationalID[16];
    // and more
};

char * fullname(struct PersonInfo pi)
{
   // ...
}
```

- The data will be copied. Not a good choice!

The problem

- One solution is to use a pointer

```
struct PersonInfo
{
   char firstname[256];
   char middlename[256];
   char lastname[256];
   char address[256];
   char nationalID[16];
    // and more
};

char * fullname(struct PersonInfo * ppi)
{
   if (ppi == NULL)
   {
      cerr << "Invalid pointer" << endl;
      return NULL;
   }
   // ...
```

References as function parameters

- No data copying in the reference version; Better efficiency
- The modification to a reference will affect the original object

```
struct Matrix
{
    int rows;
    int cols;
    float * pData;
};

float matrix_max(struct Matrix mat)
{
    float max = FLT_MIN;
    //find max value of mat
    for(int r = 0; r < mat.rows; r++)
        for (int c = 0; c < mat.cols; c++)
        {
            float val = mat.pData[ r * mat.cols + c];
            max = ( max > val ? max : val);
        }
    return max;
```

```
struct Matrix
{
    int rows;
    int cols;
    float * pData;
};

float matrix_max(struct Matrix & mat)
{
    float max = FLT_MIN;
    //find max value of mat
    for(int r = 0; r < mat.rows; r++)
        for (int c = 0; c < mat.cols; c++)
        {
            float val = mat.pData[ r * mat.cols + c];
            max = ( max > val ? max : val);
        }
    return max;
```

References as function parameters

- To avoid the data is modified by mistakes,

```
float matrix_max(const struct Matrix & mat)
{
   float max = FLT_MIN;
   // ...
   return max;
}
```

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Return statement

Return statement

- Statement `return;` is only valid if the function return type is `void`.
- Just finish the execution of the function, no value returned.

```
void print_gender(bool isMale)
{
   if(isMale)
      cout << "Male" << endl;
   else
      cout << "Female" << endl;

   return;
}
```

```
void print_gender(bool isMale)
{
   if(isMale)
      cout << "Male" << endl;
   else
      cout << "Female" << endl;
}
```

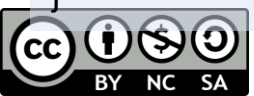
Return statement

- The return type can be a fundamental type or a compound type.
- Pass by value:
  - Fundamental types: the value of a constant/variable is copied
  - Pointers: the address is copied
  - Structures: the whole structure is copied

```
float maxa = matrix_max(matA);

Matrix * pMat = create_matrix(4,5);
```

```
Matrix * create_matrix(int rows, int cols)
{
   Matrix * p = new Matrix{rows, cols};
   p->pData = new float[p->rows * p->cols]{1.f, 2.f, 3.f};
   // you should check if the memory is allocated successfully
   // and don't forget to release the memory
   return p;
}
```



If we have a lot to return

- Such as a matrix addition function (A+B->C)
- A suggested prototype:
  - To use references to avoid data copying
  - To use const parameters to avoid the input data is modified
  - To use non-const reference parameters to receive the output

```
bool matrix_add(const Matrix & matA, const Matrix & matB, Matrix & matC)
{
   // check the dimensions of the three matrices
   // re-create matC if needed
   // do: matC = matA + matB
   // return true if everything is right
}
```

Similar mechanism in OpenCV

- Matrix add in OpenCV

https://github.com/opencv/opencv/blob/master/modules/core/src/arithm.cpp

https://github.com/opencv/opencv/blob/master/modules/core/src/arithm.cpp

```
913  void cv::add( InputArray src1, InputArray src2, OutputArray dst,
914                InputArray mask, int dtype )
915  {
916      CV_INSTRUMENT_REGION();
917
918      arithm_op(src1, src2, dst, mask, dtype, getAddTab(), false, 0, OCL_OP_ADD );
919  }
```

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Inline functions

Inline functions

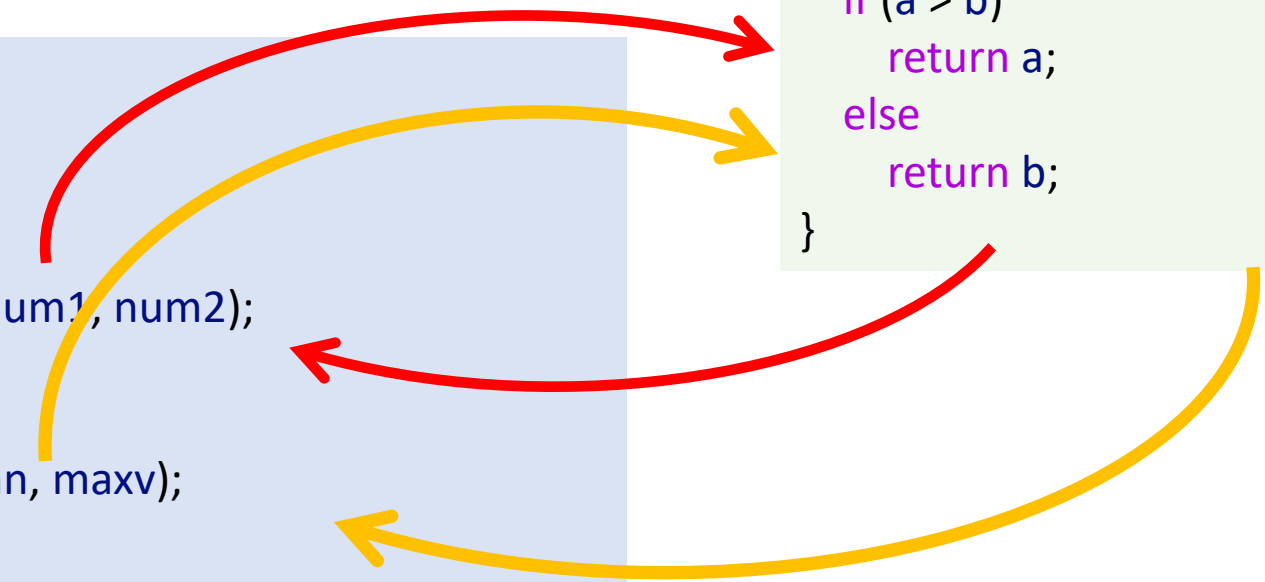
- Stack operations and jumps are needed for a function call.
- It is a heavy cost for some frequently called tiny functions.

```
int main()
{
    int num1 = 20;
    int num2 = 30;
    int maxv = max_function(num1, num2);


    maxv = max_function(numn, maxv);

}
```

```
float max_function(float a, float b)
{
    if (a > b)
        return a;
    else
        return b;
}
```



Inline functions

- The generated instructions by a compiler can be as follows to improve efficiency

```
int main()
{
   int num1 = 20;
   int num2 = 30;
   int maxv =
          {if (num1 > num2)
              return num1;
            else
              return num2;}
   maxv =
          {if (numn > maxv)
              return numn;
            else
              return maxv;}

}
```

Inline functions

- inline **suggests** the compiler to perform that kind of optimizations.
- The compiler may not follow your suggestion if the function is too complex or contains some constrains.
- Some functions without inline may be optimized as an inline one.

```
inline float max_function(float a, float b)
{
   if (a > b)
      return a;
   else
      return b;
}
```

Why not use a macros?

```
#define MAX_MACRO(a, b) (a)>(b) ? (a) : (b)
```

- The source code will be replaced by a preprocessor.
- Surely no cost of a function call,
- And `a`, `b` can be any types which can compare.

inline.cpp

Inline in OpenCV

```
#ifndef CV_ALWAYS_INLINE
#if defined(__GNUC__) && (__GNUC__ > 3 || (__GNUC__ == 3 && __GNUC_MINOR__ >= 1))
#define CV_ALWAYS_INLINE inline __attribute__((always_inline))
#elif defined(_MSC_VER)
#define CV_ALWAYS_INLINE __forceinline
#else
#define CV_ALWAYS_INLINE inline
#endif
#endif
```

inline /

Pull req

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735 code res

3rdparty/caroten

```
94  template <> struct VecTraits<f32, 4> { typedef float32x4x4_t vec128; typede
    float32x2x4_t vec64; typedef VecTraits< u32, 3> unsign; };
95
96  ////////////////////////////// vld1q ////////////////////////
97
98  inline  uint8x16_t vld1q(const u8  * ptr) { return  vld1q_u8(ptr); }
99  inline   int8x16_t vld1q(const s8  * ptr) { return  vld1q_s8(ptr); }
100 inline  uint16x8_t vld1q(const u16 * ptr) { return vld1q_u16(ptr); }
```

C++ Showing the top three matches Last indexed on 26 Jun 2018

modules/imgproc/src/fixedpoint.inl.hpp

```
18      fixedpoint64(int64_t _val) : val(_val) {}
19      static CV_ALWAYS_INLINE uint64_t fixedround(const uint64_t& _val) { ret
    ((1LL << fixedShift) >> 1)); }
...
24      typedef int64_t raw_t;
25      CV_ALWAYS_INLINE fixedpoint64() { val = 0; }
26      CV_ALWAYS_INLINE fixedpoint64(const fixedpoint64& v) { val = v.val; }
```