C/C++ Program Design

CS205

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C/C++ with ARM

Intel vs ARM

- With the help of C/C++ compilers, C and C++ are platform independent.
- But we need to know some background information on different CPUs.
- Intel achieved a dominant position the personal computer market. But recently ...

ARM

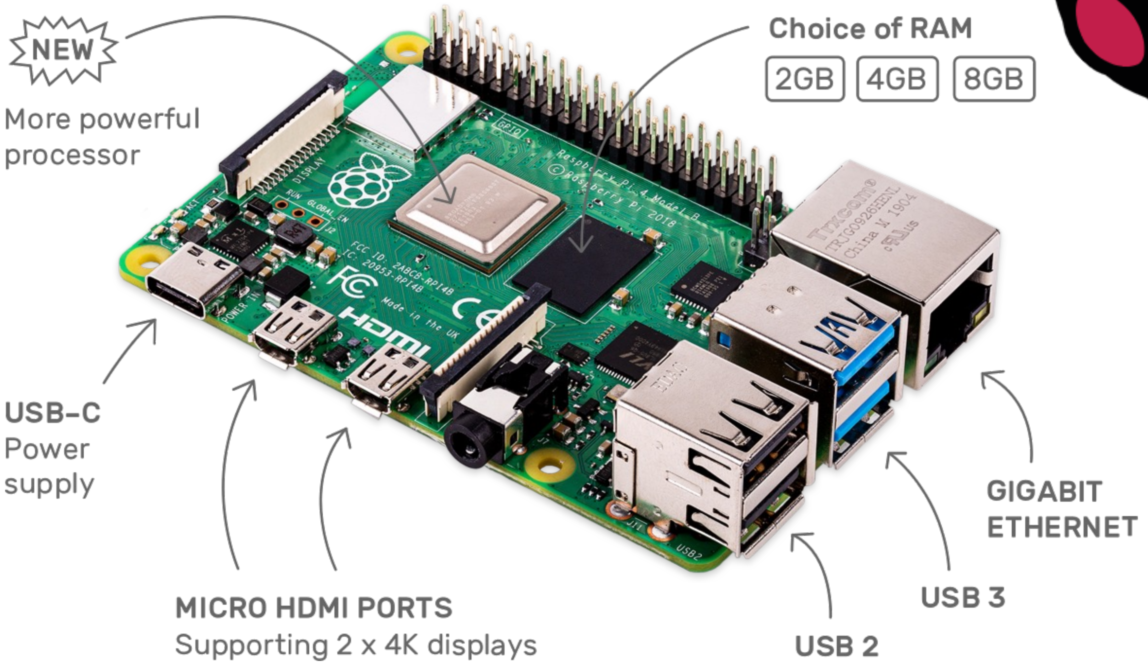
- **ARM** (previously an acronym for Advanced RISC Machine and originally Acorn RISC Machine) is a family of reduced instruction set computing (RISC) architectures for computer processors[1].
- ARM is the most widely used instruction set architecture (ISA) and the ISA produced in the largest quantity.

[1] https://en.wikipedia.org/wiki/ARM_architecture

Raspberry Pi 4

https://www.raspberrypi.org/

- Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
- 2GB, 4GB or 8GB LPDDR4-3200 SDRAM (depending on model)
- 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0, BLE
- Gigabit Ethernet
- 2 USB 3.0 ports; 2 USB 2.0 ports.
- Raspberry Pi standard 40 pin GPIO header (fully backwards compatible with previous boards)
- 2 × micro-HDMI ports (up to 4kp60 supported)



How to develop programs with ARM Development boards

Almost the same with an X86 PC with Linux OS.

- gcc/g++
- Makefile
- cmake

Speedup Your Program

Principle for Programming

Simple is Beautiful !

Short

Simple

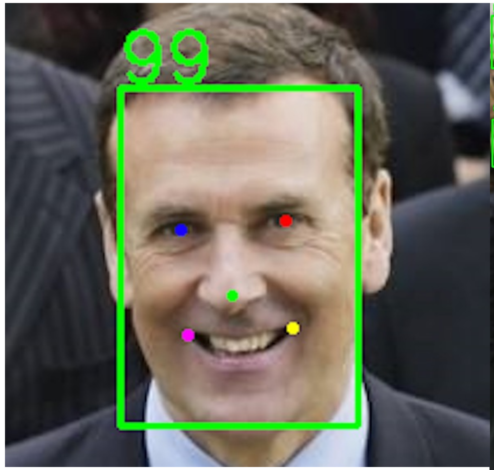
Efficient

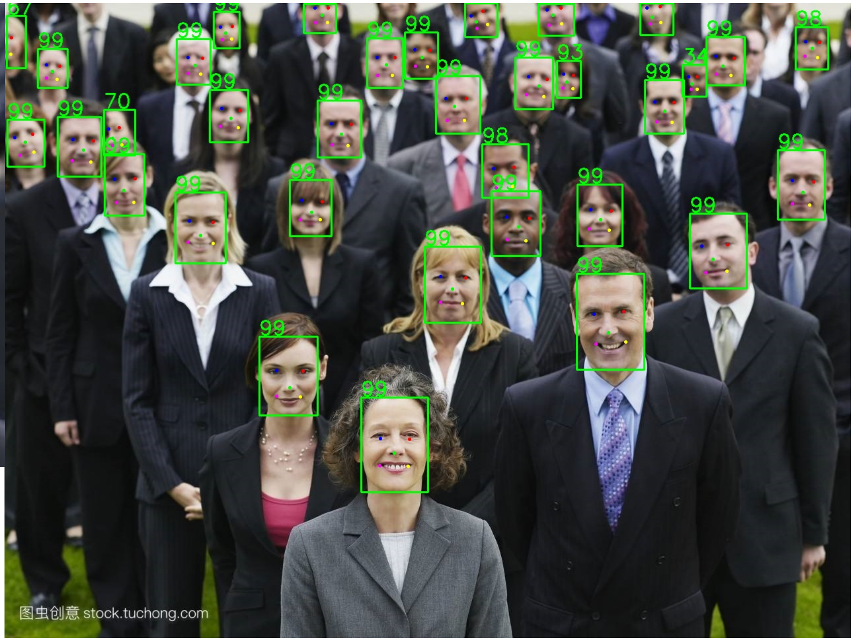
Some Tips on Optimization

- Choose an appropriate algorithm
- Clear and simple code for the compiler to optimize
- Optimize code for memory
- Do not copy large memory
- No printf()/cout in loops
- Table lookup (sin(), cos() ...)
- SIMD, OpenMP

An example: libfacedetection

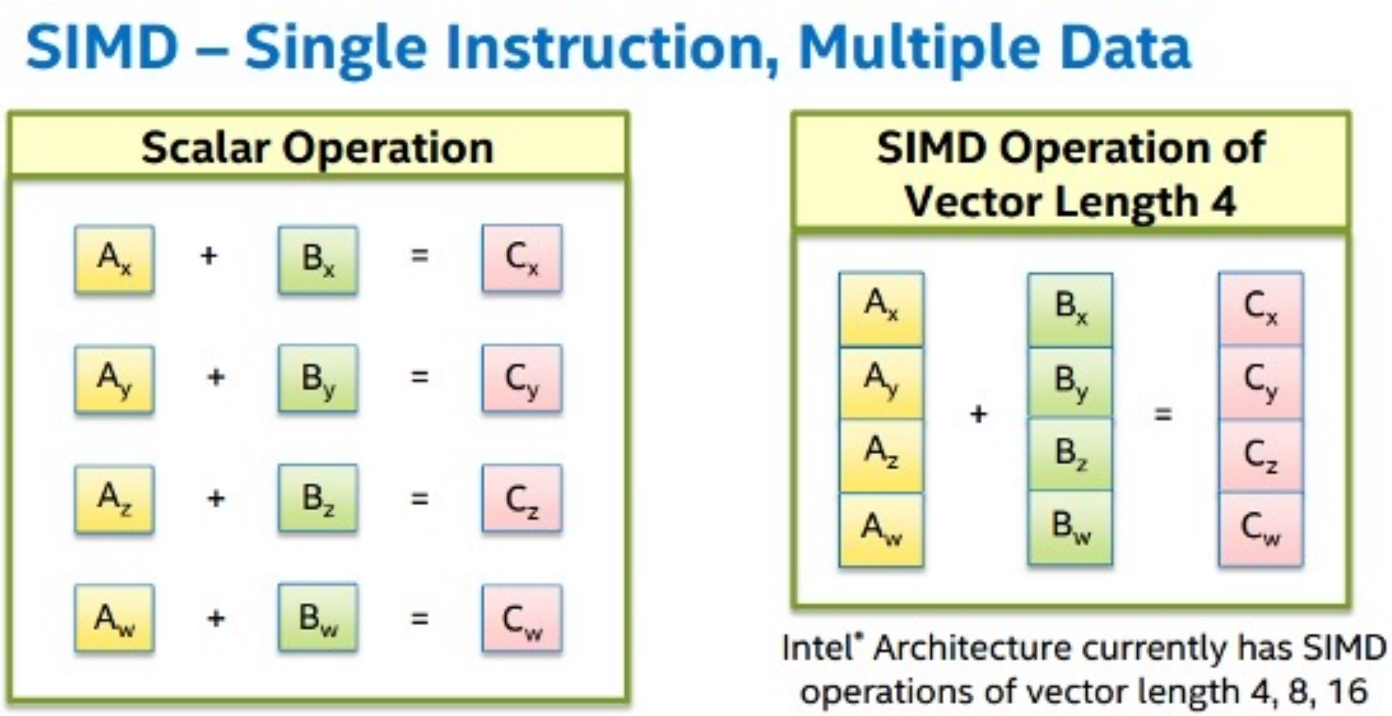
- Face detection and facial landmark detection in **1600 lines** of source code
  - ➢ facedetectcnn.h :
    - ✓400 lines
    - ✓CNN APIs
  - ➢ facedetectcnn.cpp:
    - ✓900 lines
    - ✓CNN function definitions
  - ➢ facedetectcnn-model.cpp:
    - ✓300 lines
    - ✓Face detection model
  - ➢ facedetectcnn-int8data.cpp
    - ✓CNN model parameters in static variables





https://github.com/ShiqiYu/libfacedetection/

SIMD: Single instruction, multiple data



Intel® Architecture currently has SIMD operations of vector length 4, 8, 16

- Intel: MMX, SSE, SSE2, AVX, AVX2, AVX512
- ARM: NEON
- RISC-V: RVV(RISC-V Vector Extension)

https://software.intel.com/sites/landingpage/IntrinsicsGuide/

SIMD in OpenCV

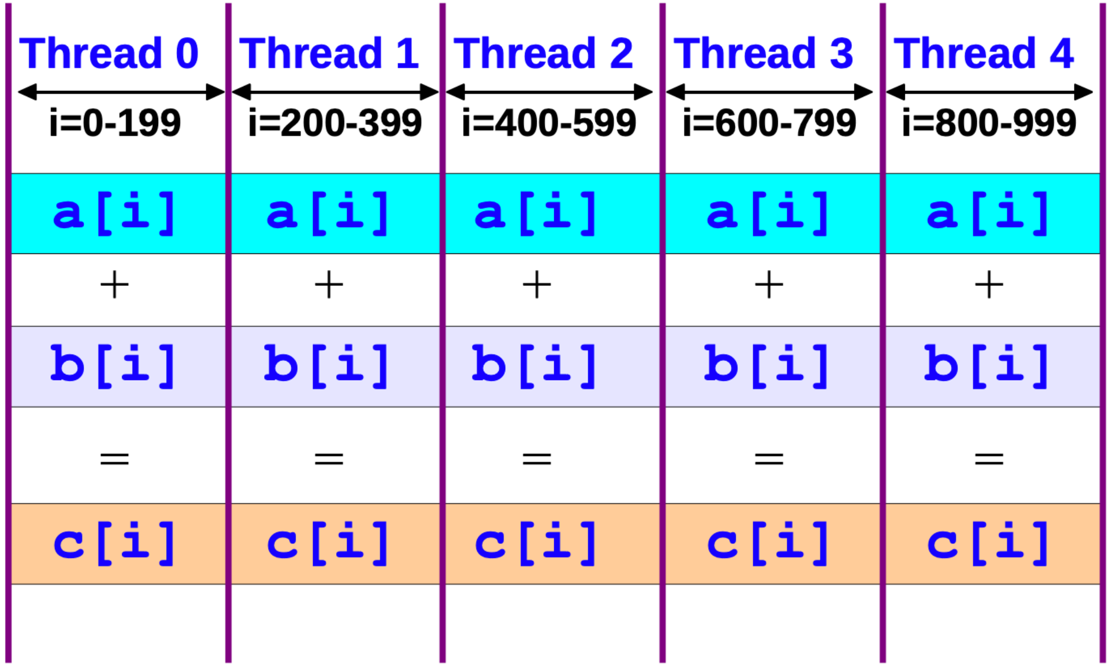
- "Universal intrinsics" is a types and functions set intended to simplify vectorization of code on different platforms.

- https://docs.opencv.org/master/df/d91/group__core__hal__intrin.html

- 使用OpenCV中的universal intrinsics为算法提速(1)(2)(3)
  - ➢ https://mp.weixin.qq.com/s/_dFQ9lDu-qjd8AaiCxYjcQ
  - ➢ https://mp.weixin.qq.com/s/3UmDImwlQwGX50b1hvz_Zw
  - ➢ https://mp.weixin.qq.com/s/XtV2ZUwDq8sZ8HlzGDRaWA

An Overview of OpenMP – Ruud van der Pas – Sun Microsystems https://www.openmp.org/wp-content/uploads/ntu-vanderpas.pdf

OpenMP®



Thread 0	Thread 1	Thread 2	Thread 3	Thread 4
i=0-199	i=200-399	i=400-599	i=600-799	i=800-999
a[i]	a[i]	a[i]	a[i]	a[i]
+	+	+	+	+
b[i]	b[i]	b[i]	b[i]	b[i]
=	=	=	=	=
c[i]	c[i]	c[i]	c[i]	c[i]

```
#include <omp.h>


#pragma omp parallel for
for (size_t i = 0; i < n; i++)
{
    c[i] = a[i] + b[i];
}
```

OpenMP®

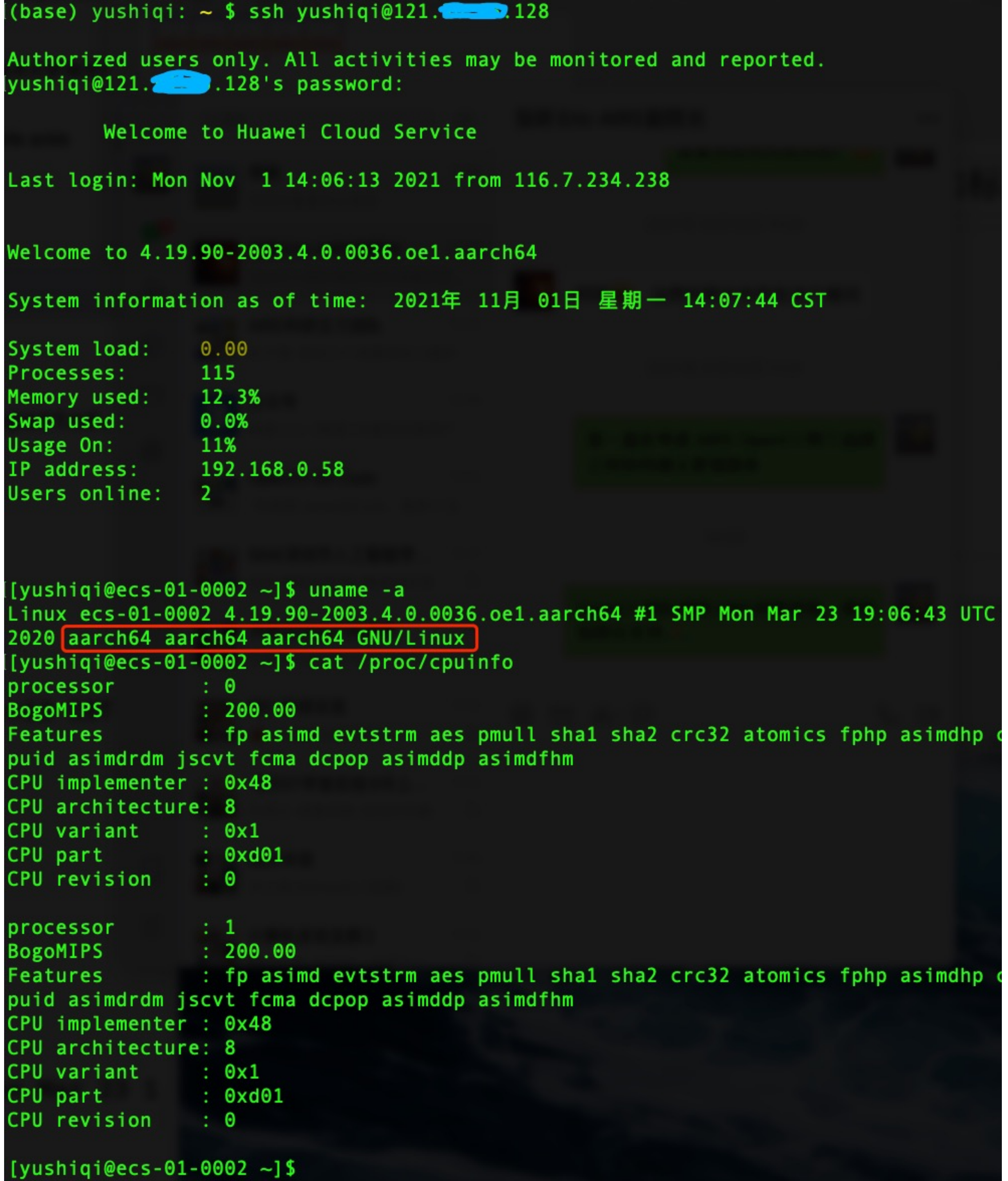
Where should #pragma be? The 1st loop or the 2nd?

```
#include <omp.h>

#pragma omp parallel for
for (size_t i = 0; i < n; i++)
{
    //#pragma omp parallel for
    for (size_t j = 0; j < n; j++)
    {
        //...
    }
}
```

An Example with SIMD and OpenMP

ARM Cloud Server

- Huawei ARM Cloud Server
- Kunpeng 920 (2 cores of many)
- RAM: 3GB
- openEuler Linux



```
(base) yushiqi: ~ $ ssh yushiqi@121.[redacted].128

Authorized users only. All activities may be monitored and reported.
yushiqi@121.[redacted].128's password:

        Welcome to Huawei Cloud Service

Last login: Mon Nov  1 14:06:13 2021 from 116.7.234.238


Welcome to 4.19.90-2003.4.0.0036.oe1.aarch64

System information as of time:  2021年 11月 01日 星期一 14:07:44 CST

System load:    0.00
Processes:      115
Memory used:    12.3%
Swap used:      0.0%
Usage On:       11%
IP address:     192.168.0.58
Users online:   2



[yushiqi@ecs-01-0002 ~]$ uname -a
Linux ecs-01-0002 4.19.90-2003.4.0.0036.oe1.aarch64 #1 SMP Mon Mar 23 19:06:43 UTC
2020 aarch64 aarch64 aarch64 GNU/Linux
[yushiqi@ecs-01-0002 ~]$ cat /proc/cpuinfo
processor       : 0
BogoMIPS        : 200.00
Features        : fp asimd evtstrm aes pmull sha1 sha2 crc32 atomics fphp asimdhp c
puid asimdrdm jscvt fcma dcpop asimddp asimdfhm
CPU implementer : 0x48
CPU architecture: 8
CPU variant     : 0x1
CPU part        : 0xd01
CPU revision    : 0

processor       : 1
BogoMIPS        : 200.00
Features        : fp asimd evtstrm aes pmull sha1 sha2 crc32 atomics fphp asimdhp c
puid asimdrdm jscvt fcma dcpop asimddp asimdfhm
CPU implementer : 0x48
CPU architecture: 8
CPU variant     : 0x1
CPU part        : 0xd01
CPU revision    : 0

[yushiqi@ecs-01-0002 ~]$
```

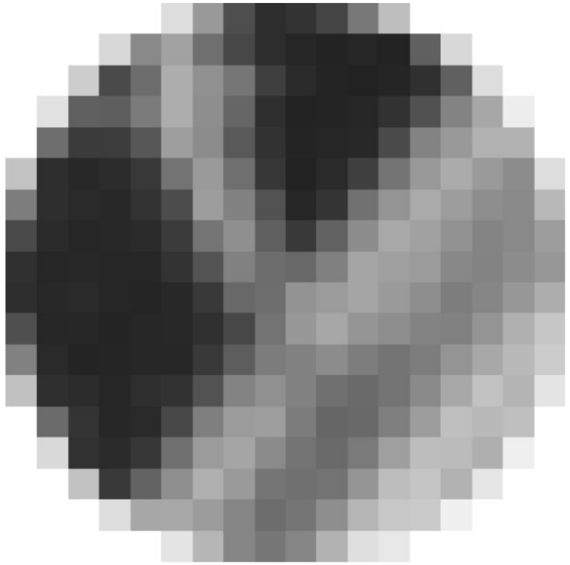
Functions for dot product

```
float dotproduct(const float *p1, const float * p2, size_t n);

float dotproduct_unloop(const float *p1, const float * p2, size_t n);

float dotproduct_avx2(const float *p1, const float * p2, size_t n);

float dotproduct_avx2_omp(const float *p1, const float * p2, size_t n);

float dotproduct_neon(const float *p1, const float * p2, size_t n);

float dotproduct_neon_omp(const float *p1, const float * p2, size_t n);
```

Avoid Memory Copy

A trick in OpenCV

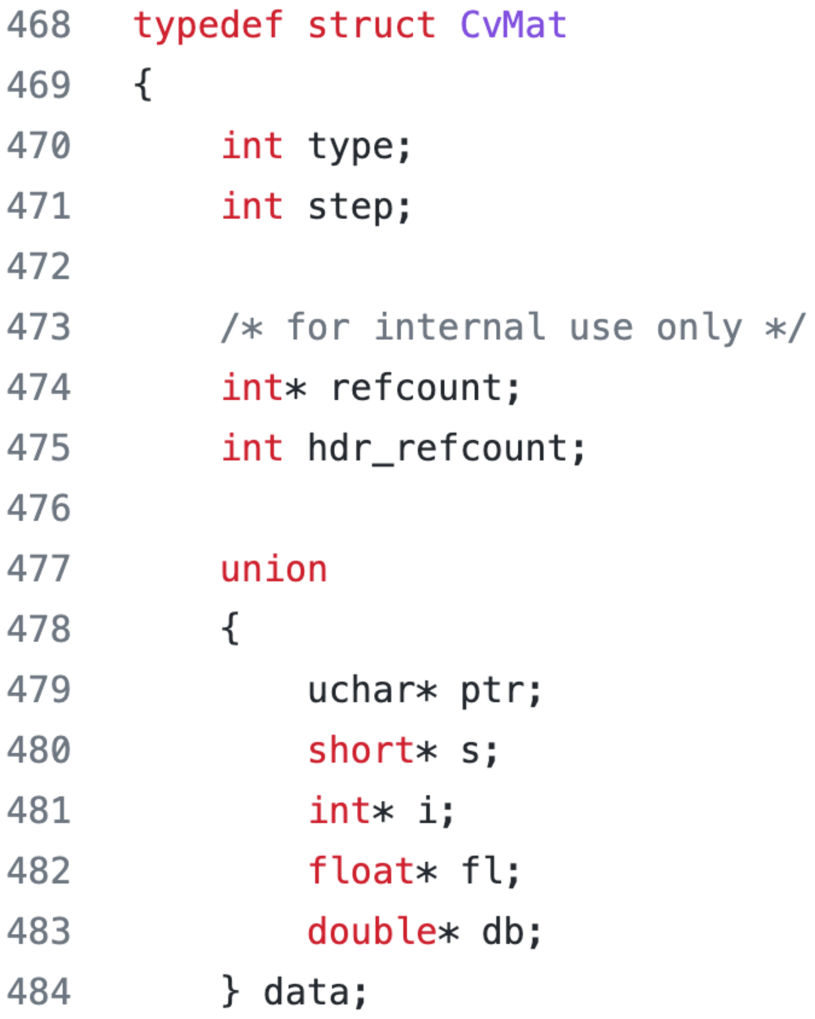
What’s an image?



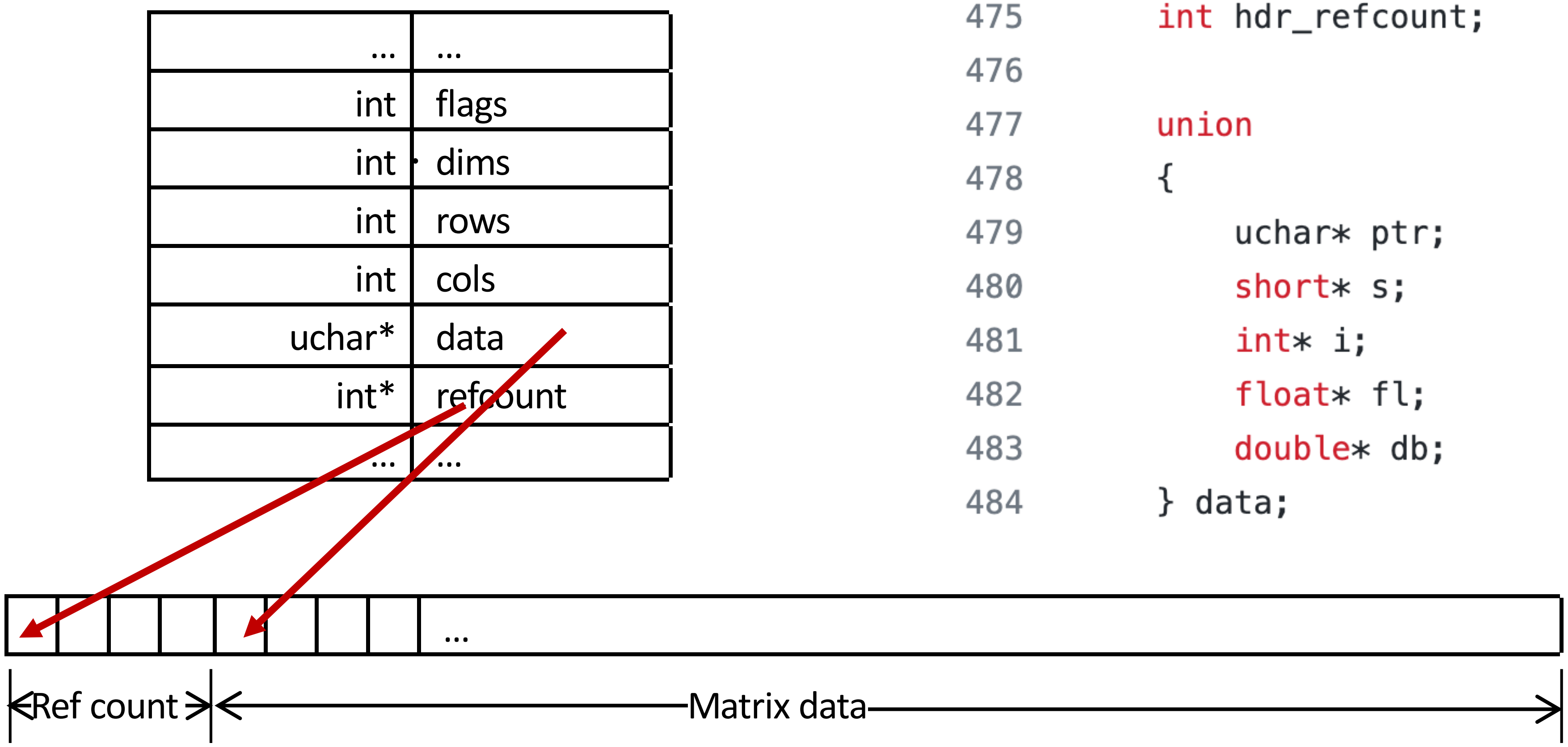
$I_{0\,0}$	$I_{0\,1}$	…	$I_{0\,N-1}$
$I_{1\,0}$	$I_{1\,1}$	…	$I_{1\,N-1}$
…	…	…	…
$I_{M-1\,0}$	$I_{M-1\,1}$	…	$I_{M-1\,N-1}$

CvMat struct

modules/core/include/opencv2/core/types_c.h



```
typedef struct CvMat
{
    int type;
    int step;

    /* for internal use only */
    int* refcount;
    int hdr_refcount;

    union
    {
        uchar* ptr;
        short* s;
        int* i;
        float* fl;
        double* db;
    } data;
```



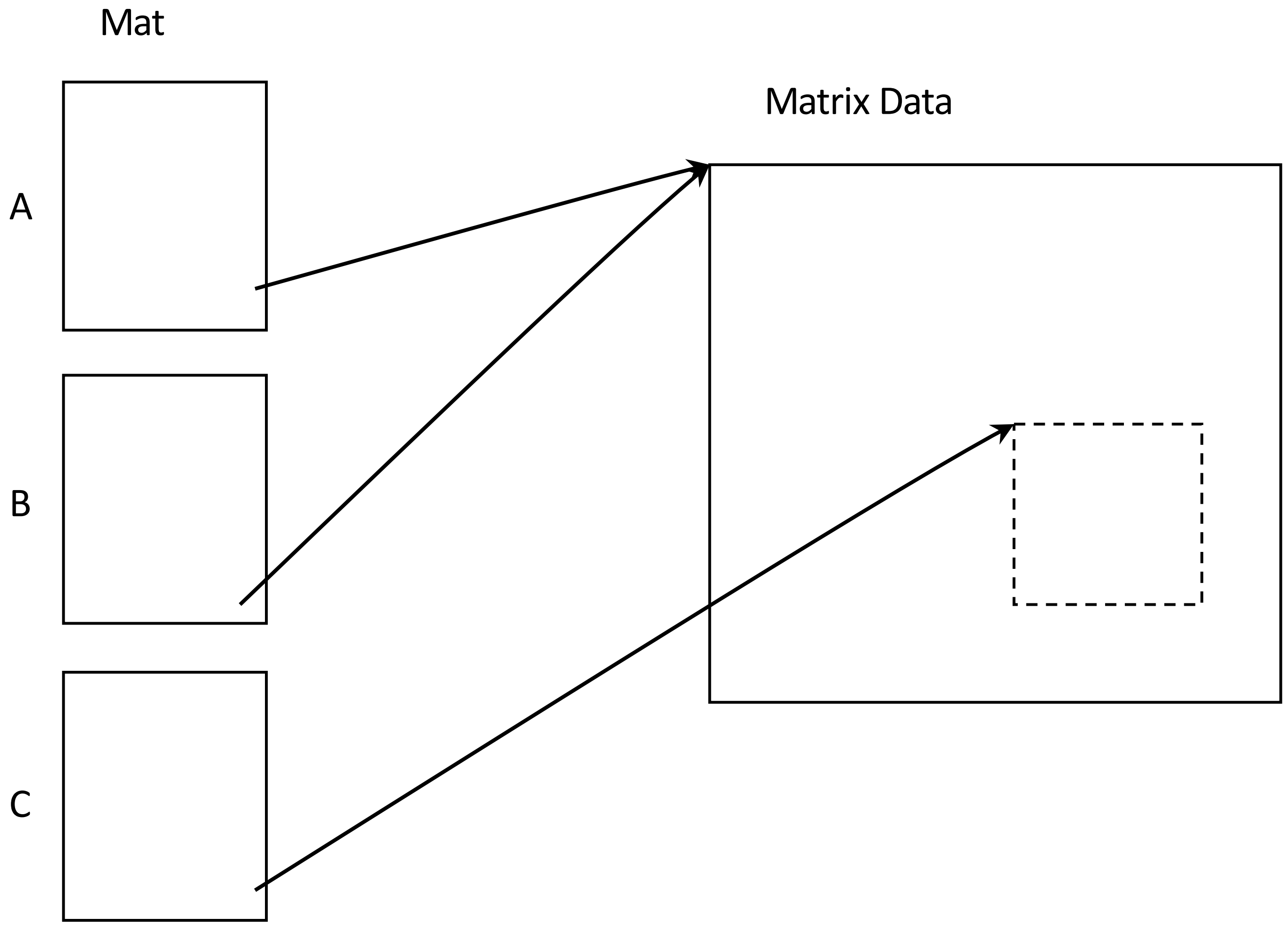
...	...
int	flags
int	dims
int	rows
int	cols
uchar*	data
int*	refcount
...	...

step in CvMat struct

- How many bytes for a row of Matrix 4(row)x3(col)?
  - ➢ Can be 3, 4, 8, and any other values >=3.
  - ➢ Memory alignment for SIMD

ROI: Region of interest

- Mat A
  - rows=100
  - cols=100
  - step=100
  - data=0xABCDEF00
- Mat B
  - rows=100
  - cols=100
  - step=100
  - data=0xABCDEF00
- Mat C
  - rows=30
  - cols=28
  - step=100
  - data=0xABCE0698


Mat
Matrix Data
A
B
C