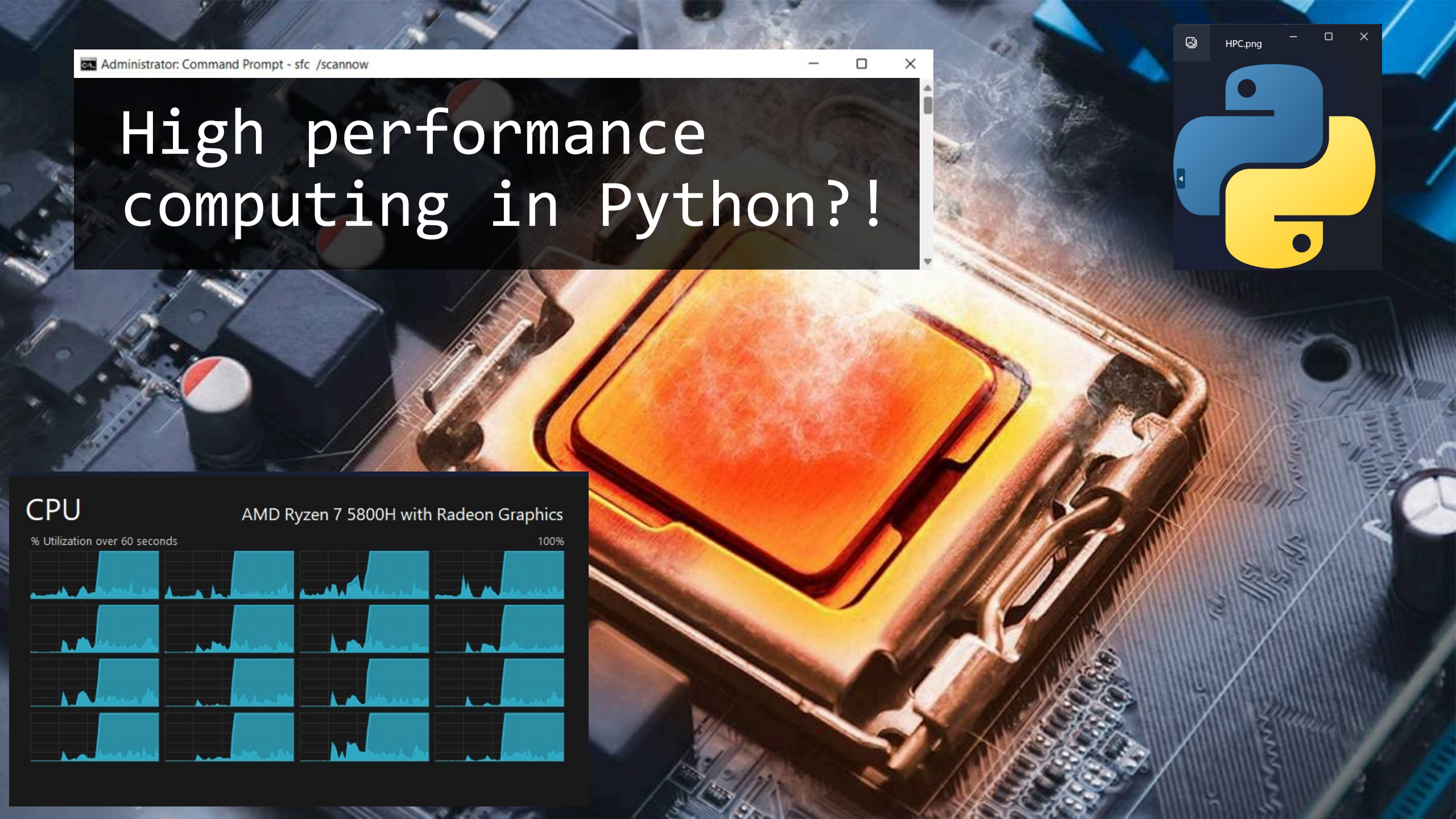
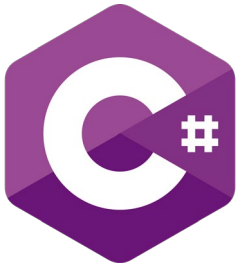

Administrator: Command Prompt - sfc /scannow
High performance computing in Python?!
HPC.png
CPU
AMD Ryzen 7 5800H with Radeon Graphics
% Utilization over 60 seconds
100%

# Miért lassú a Python?

## Fordított nyelvek

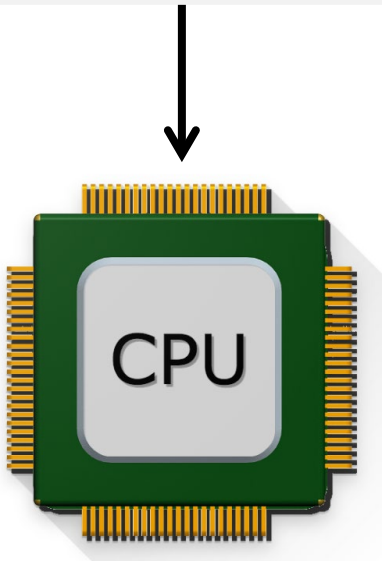


## Interpretált nyelvek



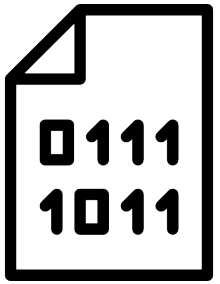

# Fordított nyelvek

```
        .global  _start
_start:
        MOV R7, #4
        MOV R0, #1
        MOV R2, #14
        LDR R1,=string
        SWI 0
        MOV R7, #1
        SWI 0
        .data
string:
        .ascii "Hello, World!\n"
```

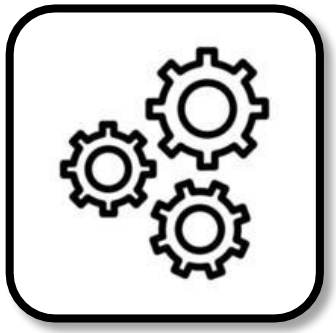




# Interpretált nyelvek

Forráskód
*example.py*




Bytekód



Interpreter
*Python.exe*

## Fordított nyelvek

```
double add(double a)
{
    return (a + a);
}
```

```
add(5);
```

```
10.0
```

```
add("five");
```

```
Error
```

## Interpretált nyelvek

```
def add(a):
    return (a + a)
```

```
add(5)
```

```
10
```

```
add(5.0)
```

```
10.0
```

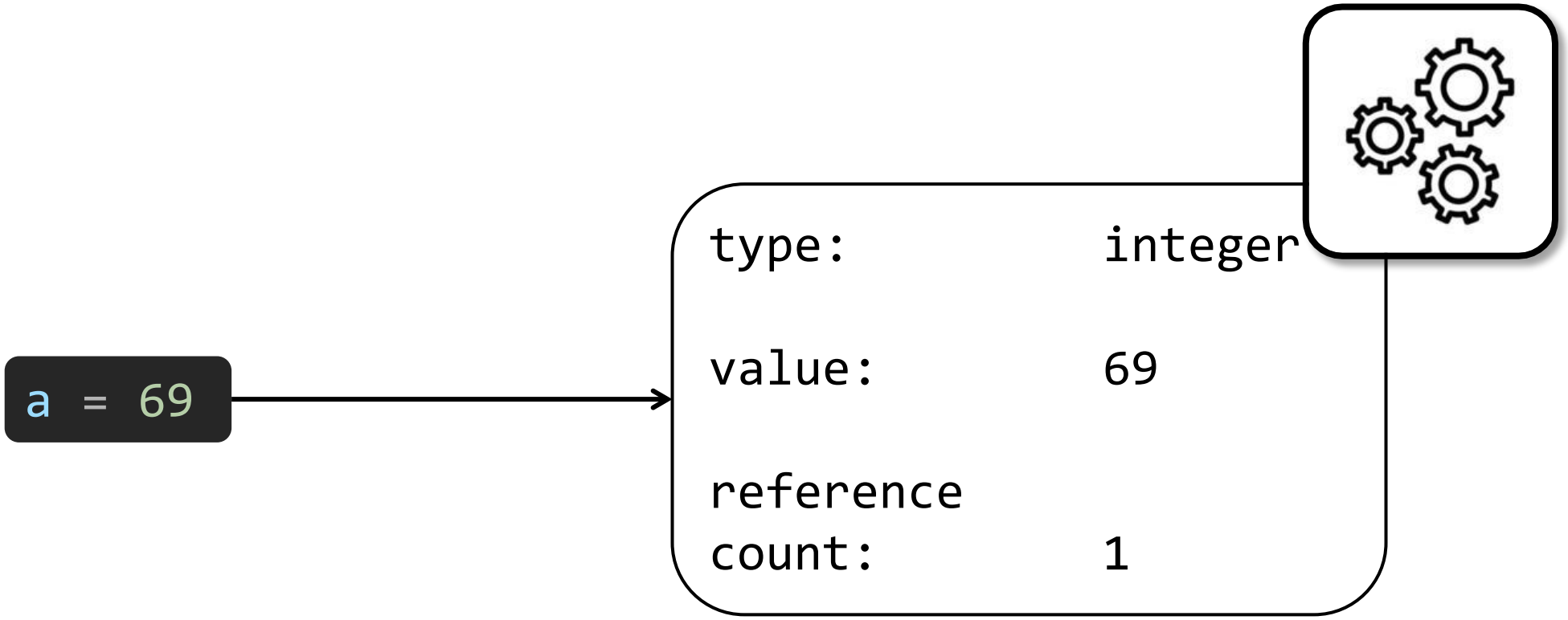
```
add('five')
```

```
’fivefive’
```

```
add([5])
```

```
[5, 5]
```

# Interpretált nyelvek



# Interpretált nyelvek

```
a = [69]          # ref = 1
b = a             # ref = 2
b.append(42)
a
```

```
[69, 42]
```

```
a = [69]                    # ref = 1

def f(b):                   # ref = 2
    b.append(42)
    return 0                # ref = 1

f(a)
```

```
a
```

```
[69, 42]
```

```
b
```

```
NameError: name 'b' is not defined
```

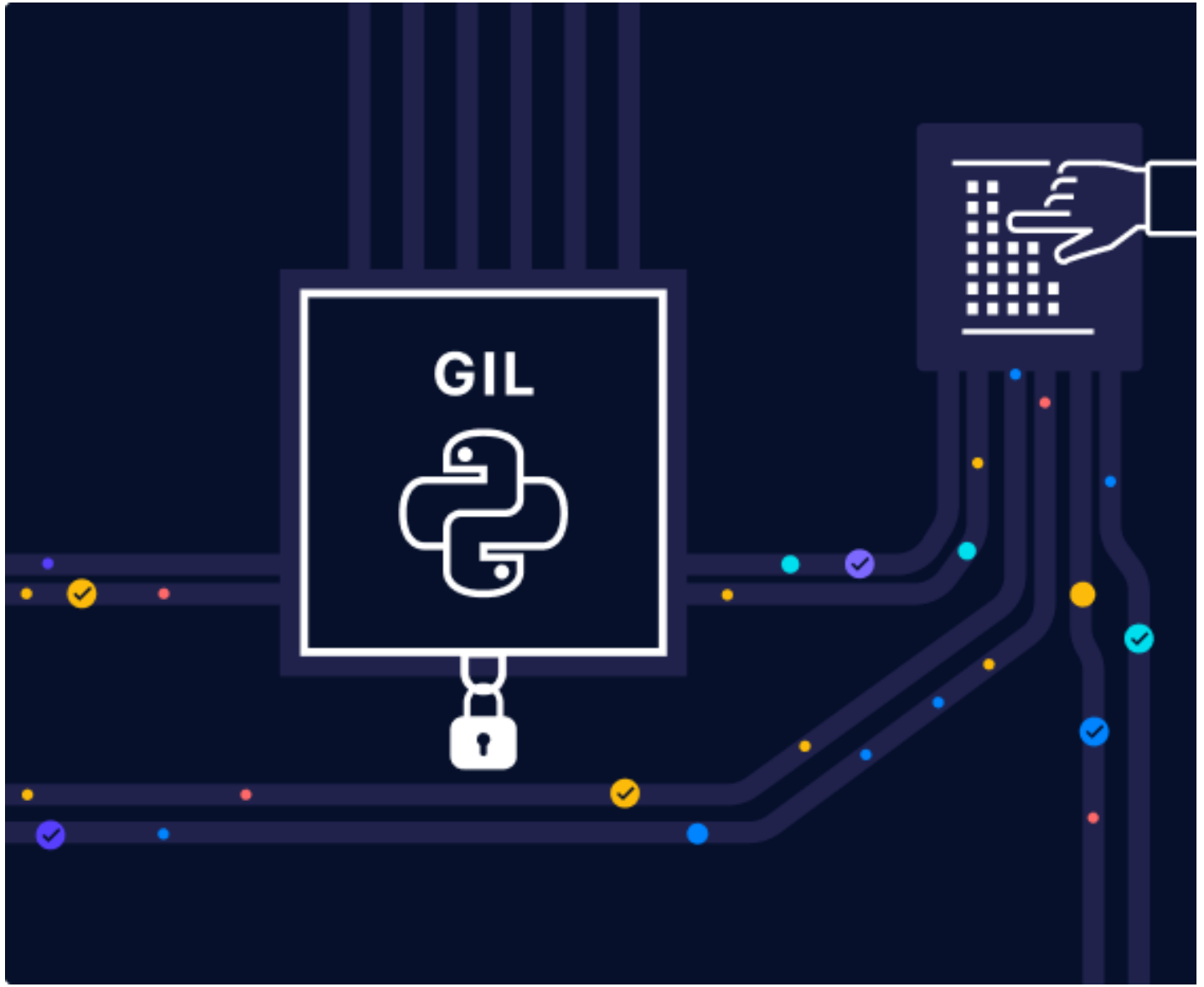
# Garbage collector

```
reference_count = 0
```

```
int* arr = new int[42];

/* ... */

delete[] arr;
```

# Global Interpreter Lock

- A Python alapvetően 1 szálon fut!




# Mit lehet tenni?

# Gépi kódra fordítás - Cython


- Python bővített változata
- C kódra fordít
- típusos

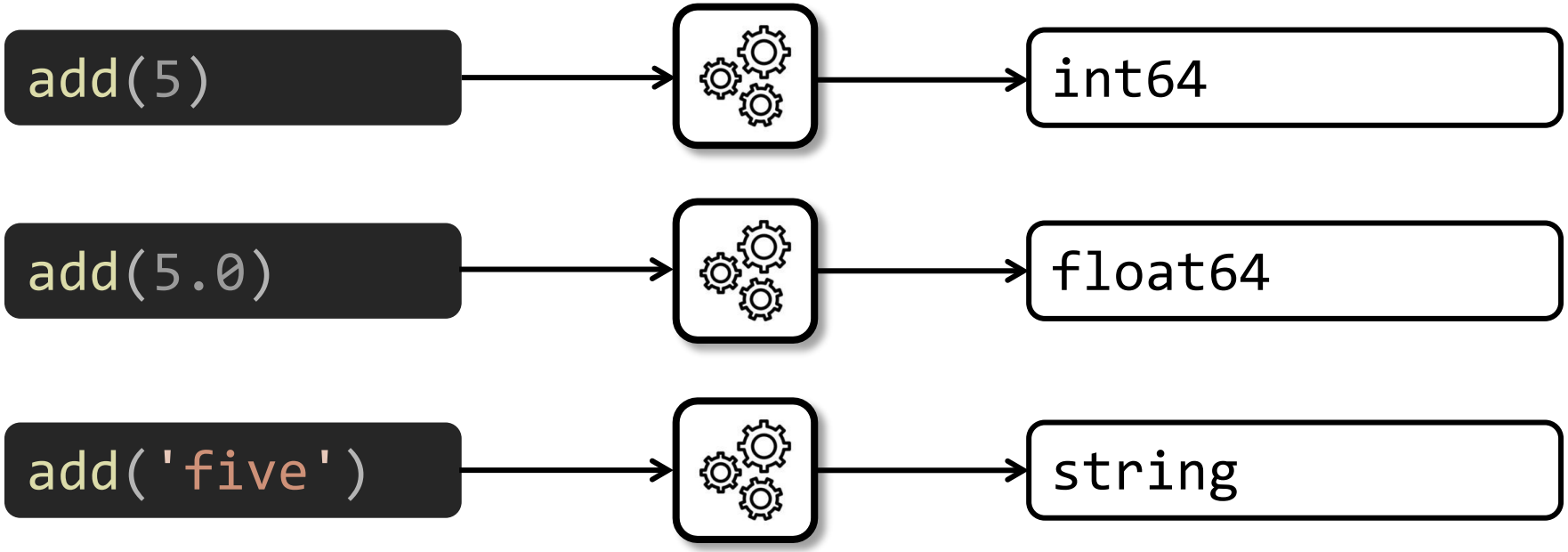
```
def f(double x):
    return x ** 2 - x

def integrate_f(double a, double b, int N):
    cdef int i
    cdef double s
    cdef double dx
    s = 0
    dx = (b - a) / N
    for i in range(N):
        s += f(a + i * dx)
    return s * dx
```

# Gépi kódra fordítás - Numba


- Just In Time (JIT) fordító
- Futási időben fordít
- Új típus >> újrafordítás

# Gépi kódra fordítás - Numba

```
@jit
def add(a):
    return (a + a)
```

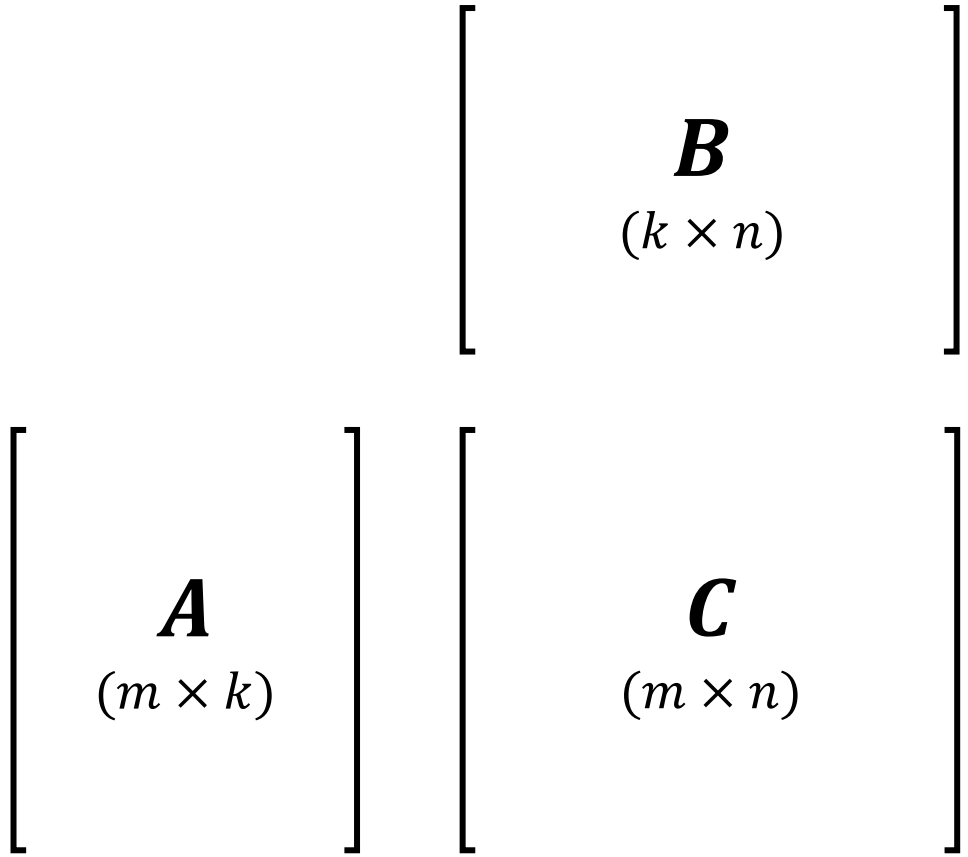



JS


Java™

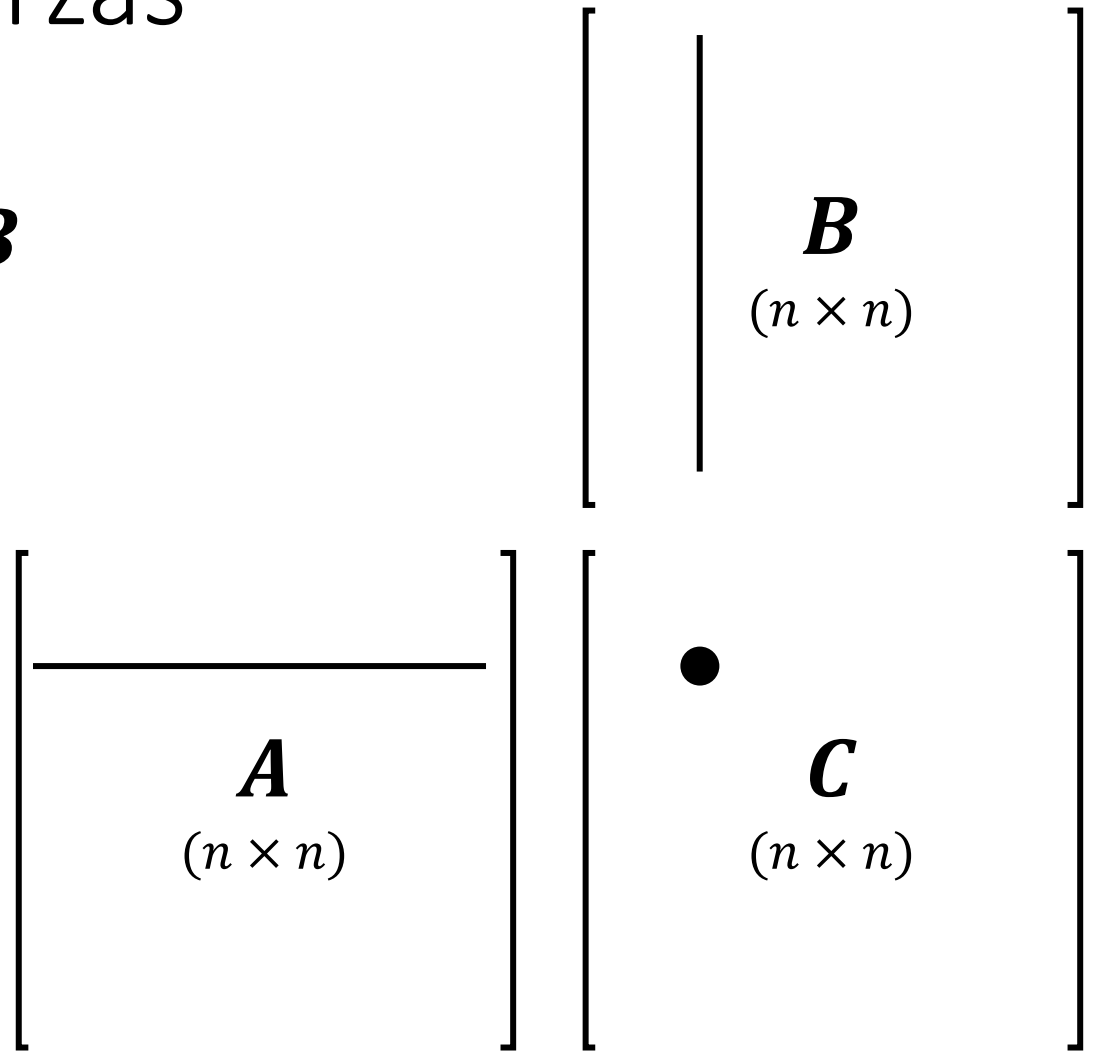
# Mátrix szorzás

$$\boldsymbol{C = AB}$$



# Mátrix szorzás

$$\boldsymbol{C = AB}$$




Összes számítás

$n \cdot n \cdot (\dots)$

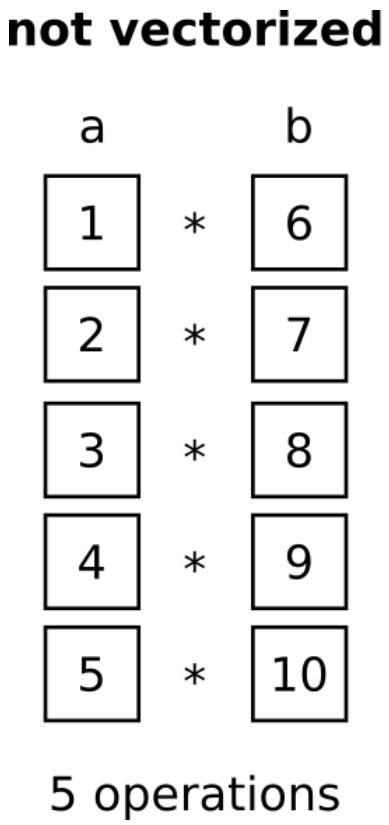
$n \cdot n \cdot (n + n - 1)$

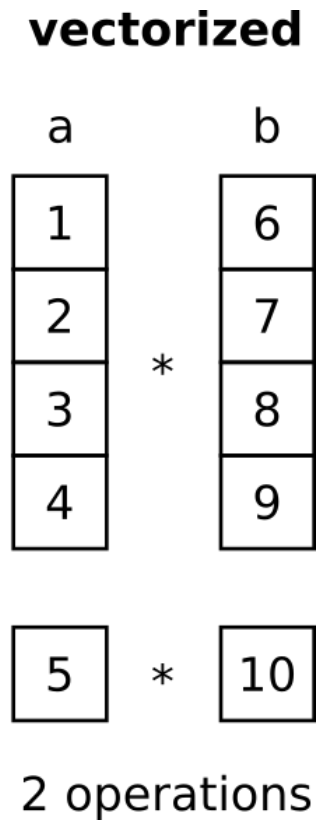
$\mathcal{O}(n^3)$

# Vektorizáció (Numpy)



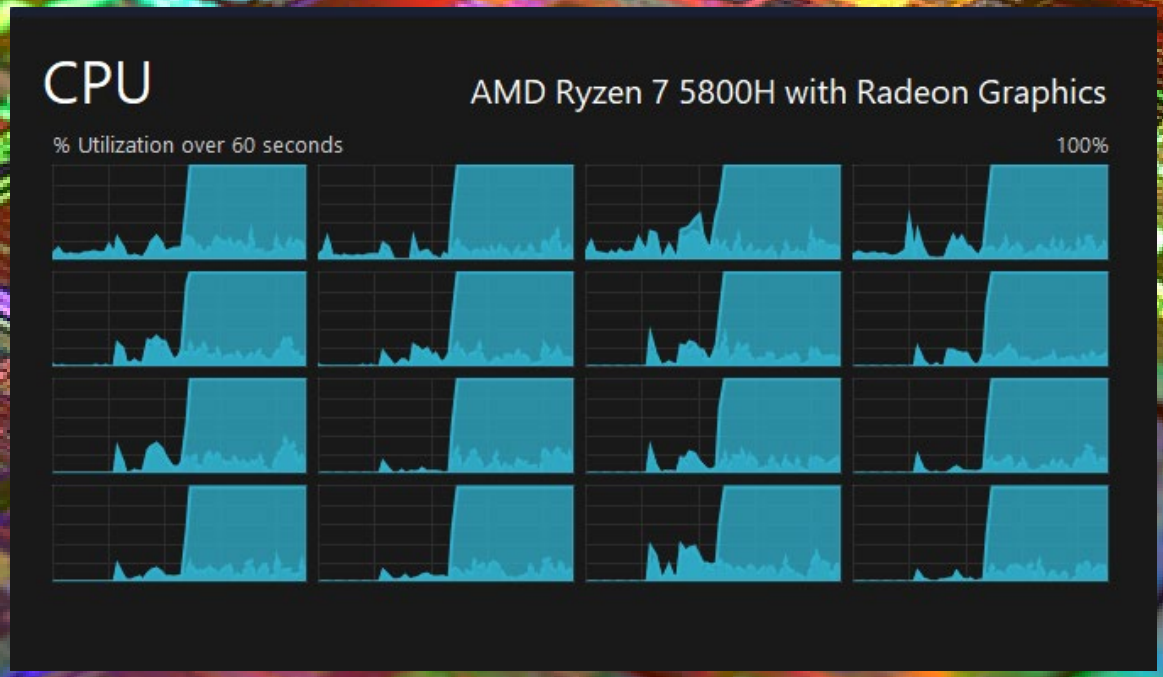
- Pytfon for ciklus: interpretált
- Numpy tömbök: gépi kód (C)



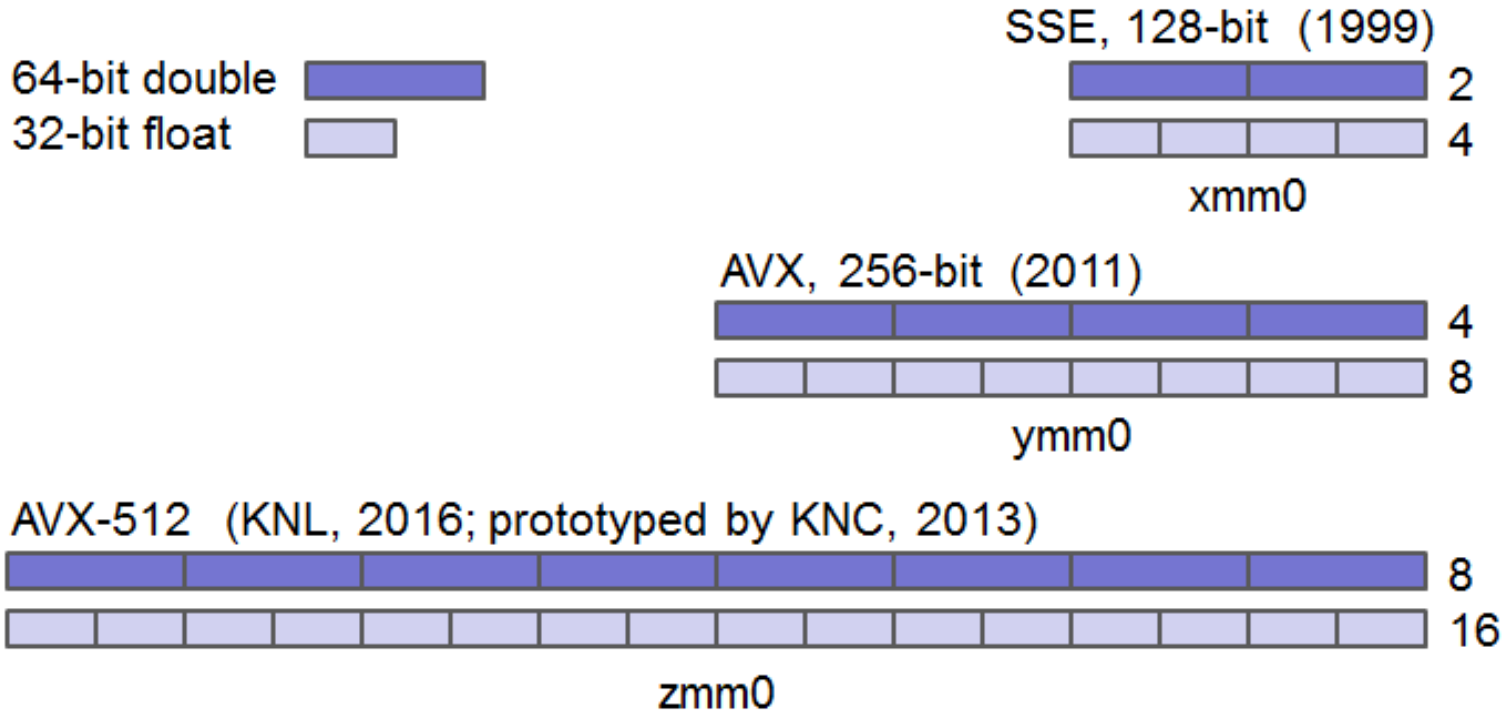
# Párhuzamosítás (CPU)

- 8 mag – 16 szál
- Szálak együttműködése! megosztott memória

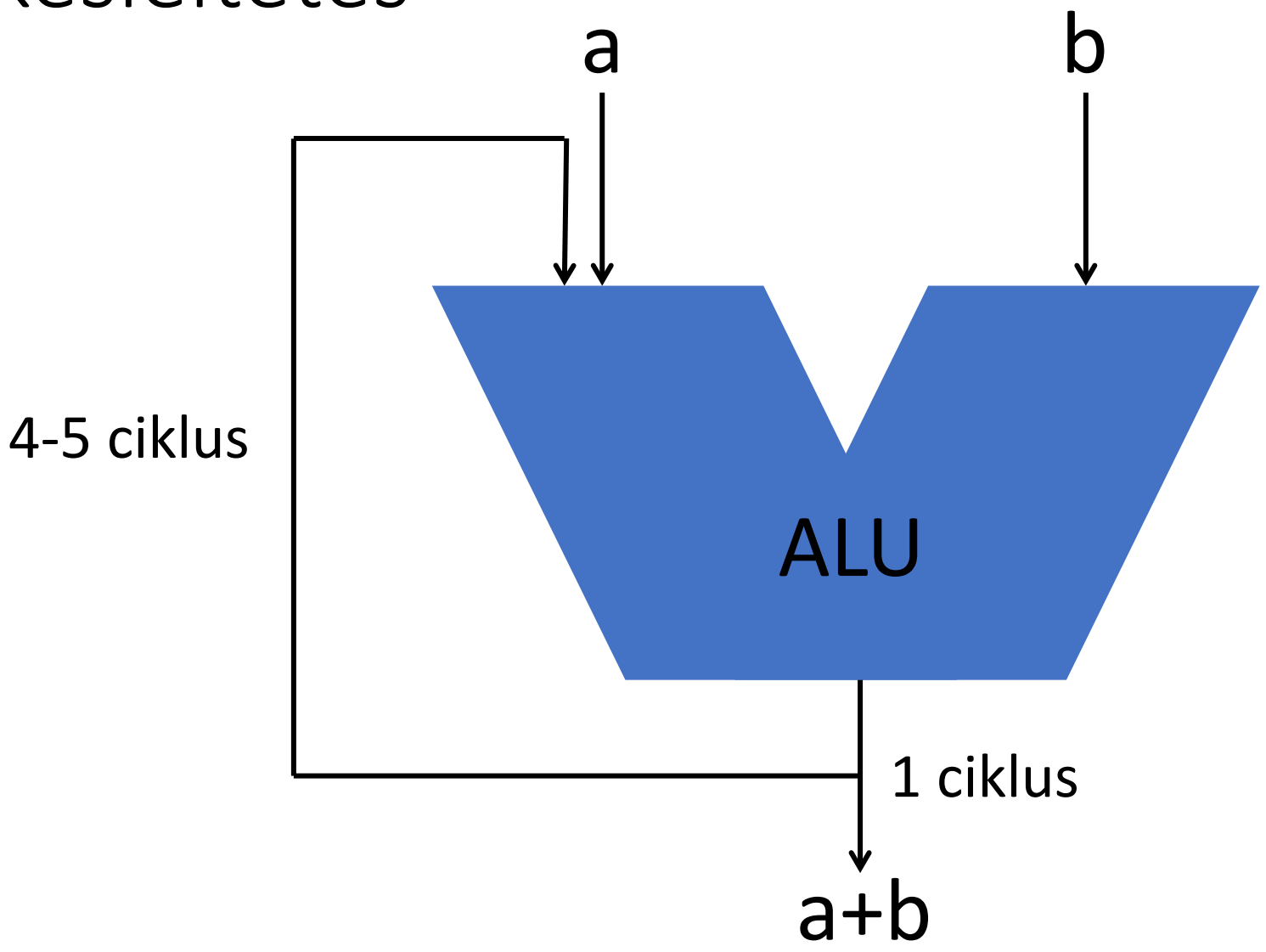


# Vektor regiszterek

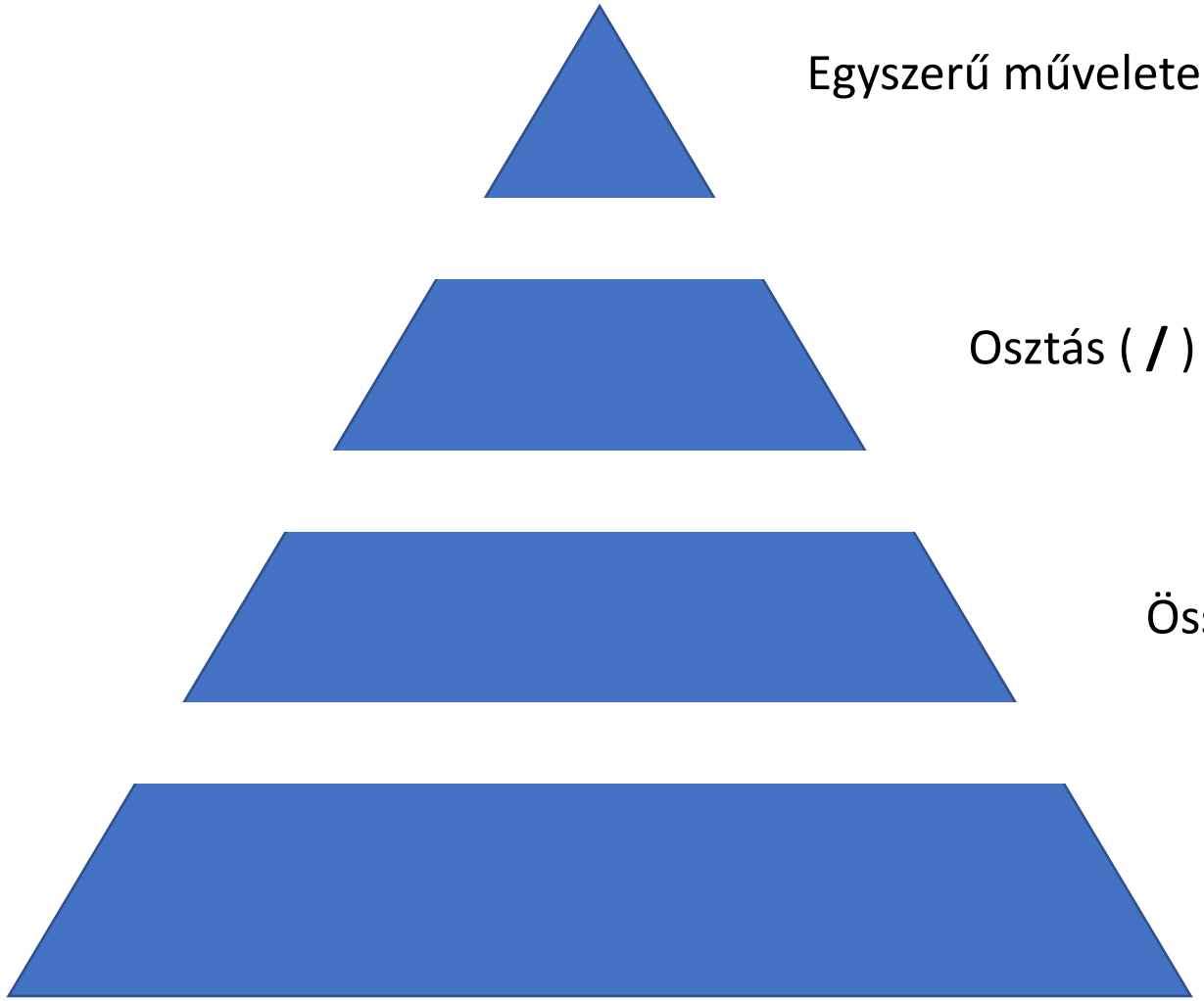
- C++ vector class library (Agner Fog)
- SIMD – Single Instruction Multiple Data



# Késleltetés



# Műveletigény

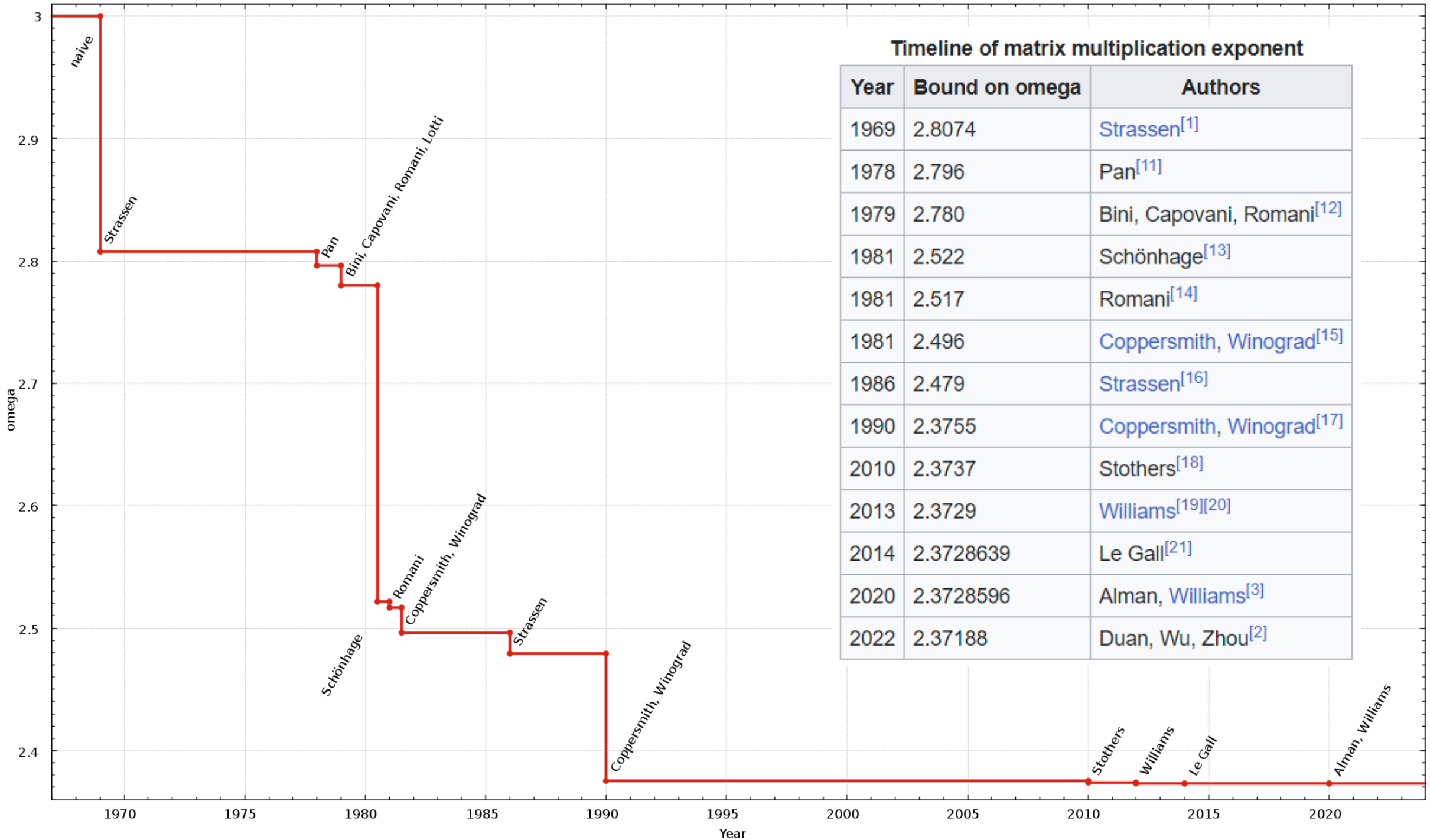


Egyszerű műveletek (**+**, *****, **or**, …)

Osztás ( **/** )

Összetett műveletek (**sqrt**, **sin**, **exp**)

OP rendszer hívások (**File_IO**, **Cosole_IO**)




**Timeline of matrix multiplication exponent**

| Year | Bound on omega | Authors |
|---|---|---|
| 1969 | 2.8074 | Strassen[1] |
| 1978 | 2.796 | Pan[11] |
| 1979 | 2.780 | Bini, Capovani, Romani[12] |
| 1981 | 2.522 | Schönhage[13] |
| 1981 | 2.517 | Romani[14] |
| 1981 | 2.496 | Coppersmith, Winograd[15] |
| 1986 | 2.479 | Strassen[16] |
| 1990 | 2.3755 | Coppersmith, Winograd[17] |
| 2010 | 2.3737 | Stothers[18] |
| 2013 | 2.3729 | Williams[19][20] |
| 2014 | 2.3728639 | Le Gall[21] |
| 2020 | 2.3728596 | Alman, Williams[3] |
| 2022 | 2.37188 | Duan, Wu, Zhou[2] |

$$z_{n+1} = z_n^2 + c$$

$c$ can be changed

$$z_0 = 0$$

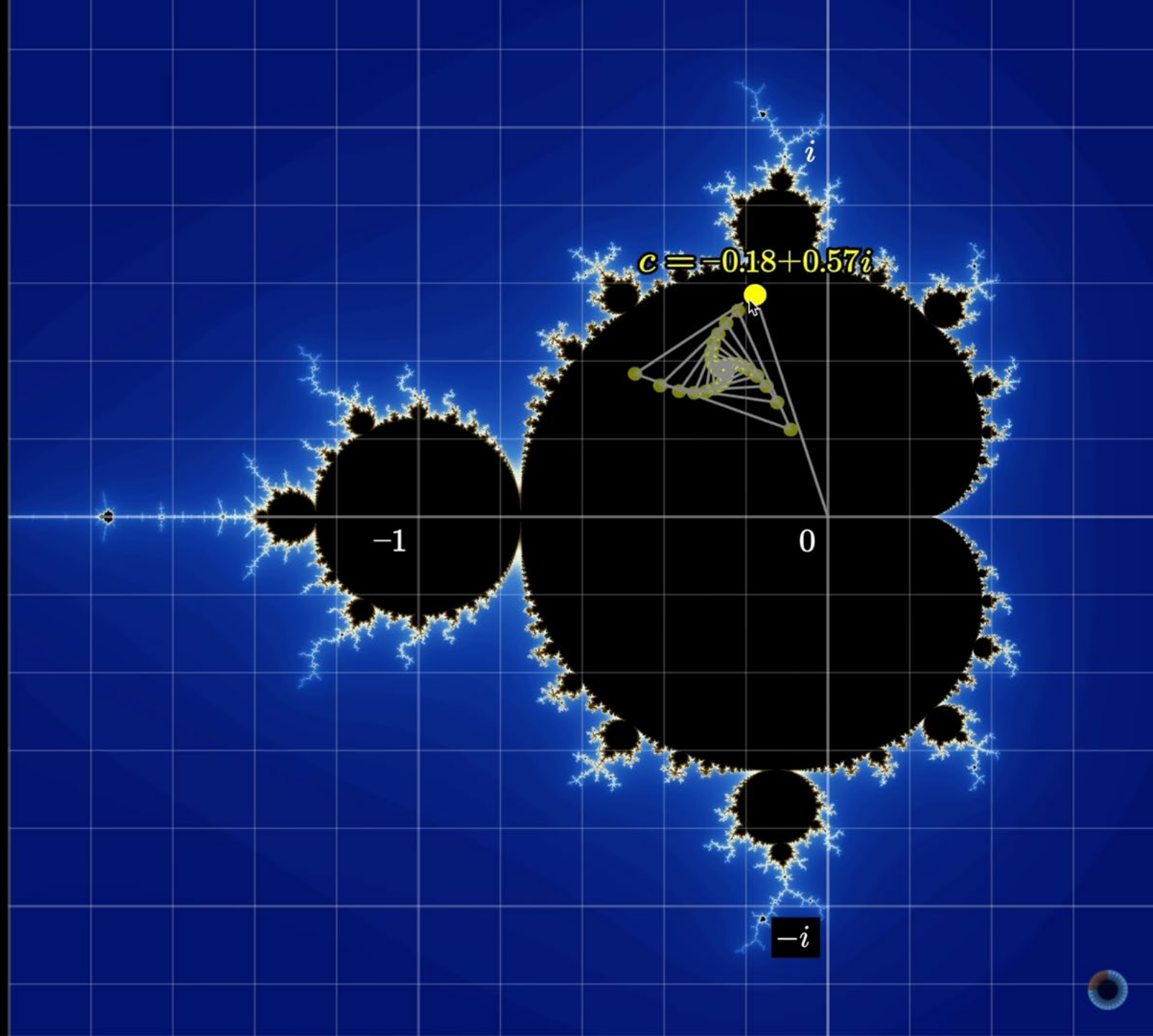
$$z_1 = 0^2 + c = c$$

$$z_2 = c^2 + c$$

$$z_3 = (c^2 + c)^2 + c$$

$$z_4 = ((c^2 + c)^2 + c)^2 + c$$

$$\vdots$$



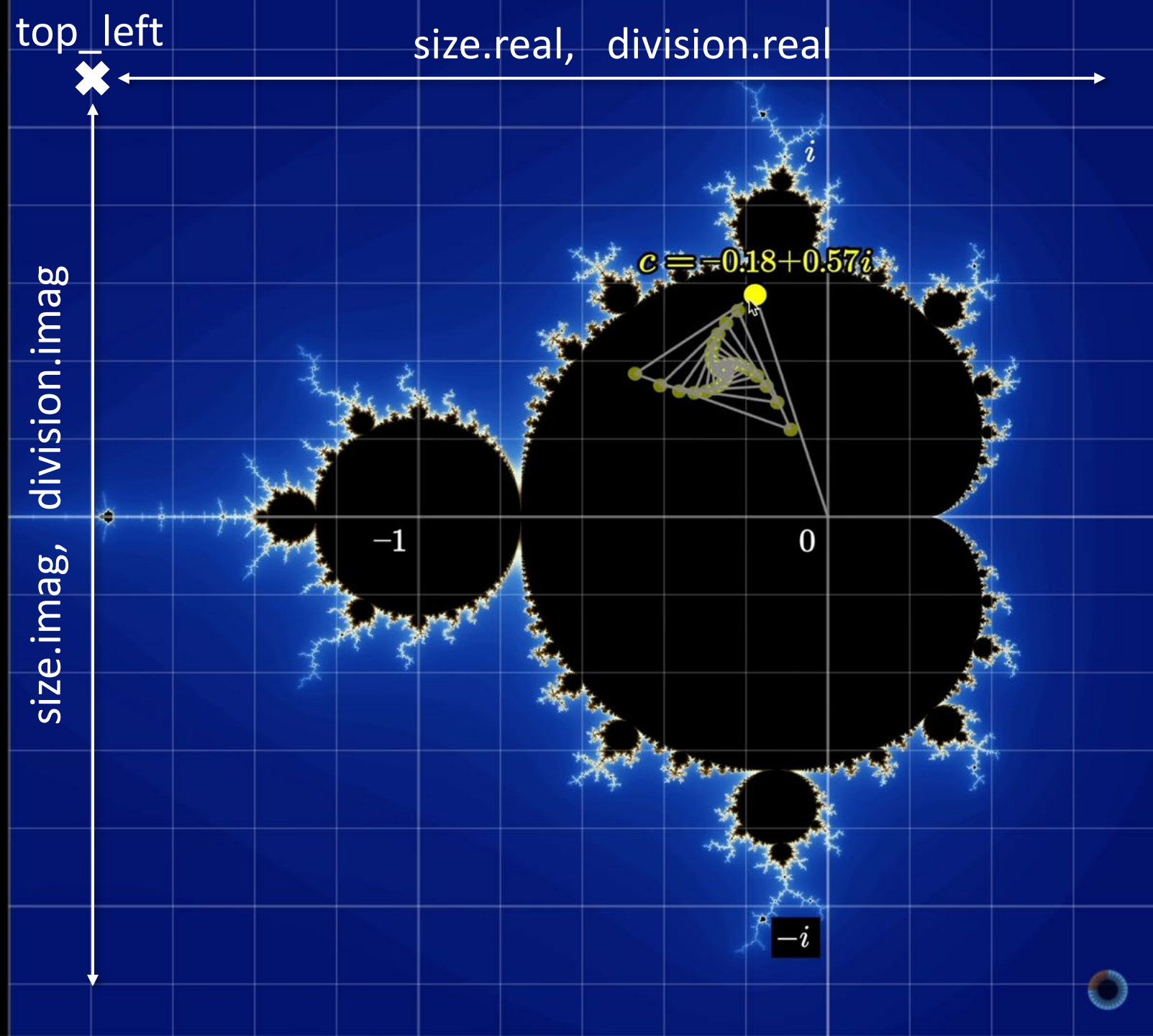
$$z_{n+1} = z_n^2 + c$$

$c$ can be changed

1. $z_0 = 0$
2. $z_1 = 0^2 + c = c$
3. $z_2 = c^2 + c$
4. $z_3 = (c^2 + c)^2 + c$
5. $z_4 = ((c^2 + c)^2 + c)^2 + c$

$\vdots$

iteration_limit



# Multiprocessing

```
import multiprocessing

def fun(x):
    return x**2

with multiprocessing.Pool() as pool:
    results = pool.imap_unordered(fun, range(10))

    for result in results:
        print(result, end=' ')
```

```
49 81 16 4 36 1 25 64 0 9
```

CPU

Regiszterek (8-16 darab/mag/típus)

4-5 ciklus

L1 cache (64 kB/mag)

8-12 ciklus

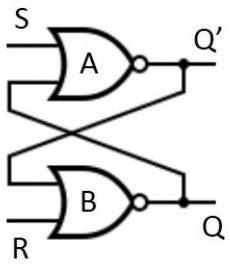
L2 cache (512 kB/mag)

40-60 ciklus

L3 cache (16 MB)

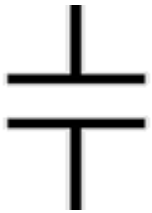
300-500 ciklus

SRAM




DRAM

RAM (32 GB)



~50000 ciklus

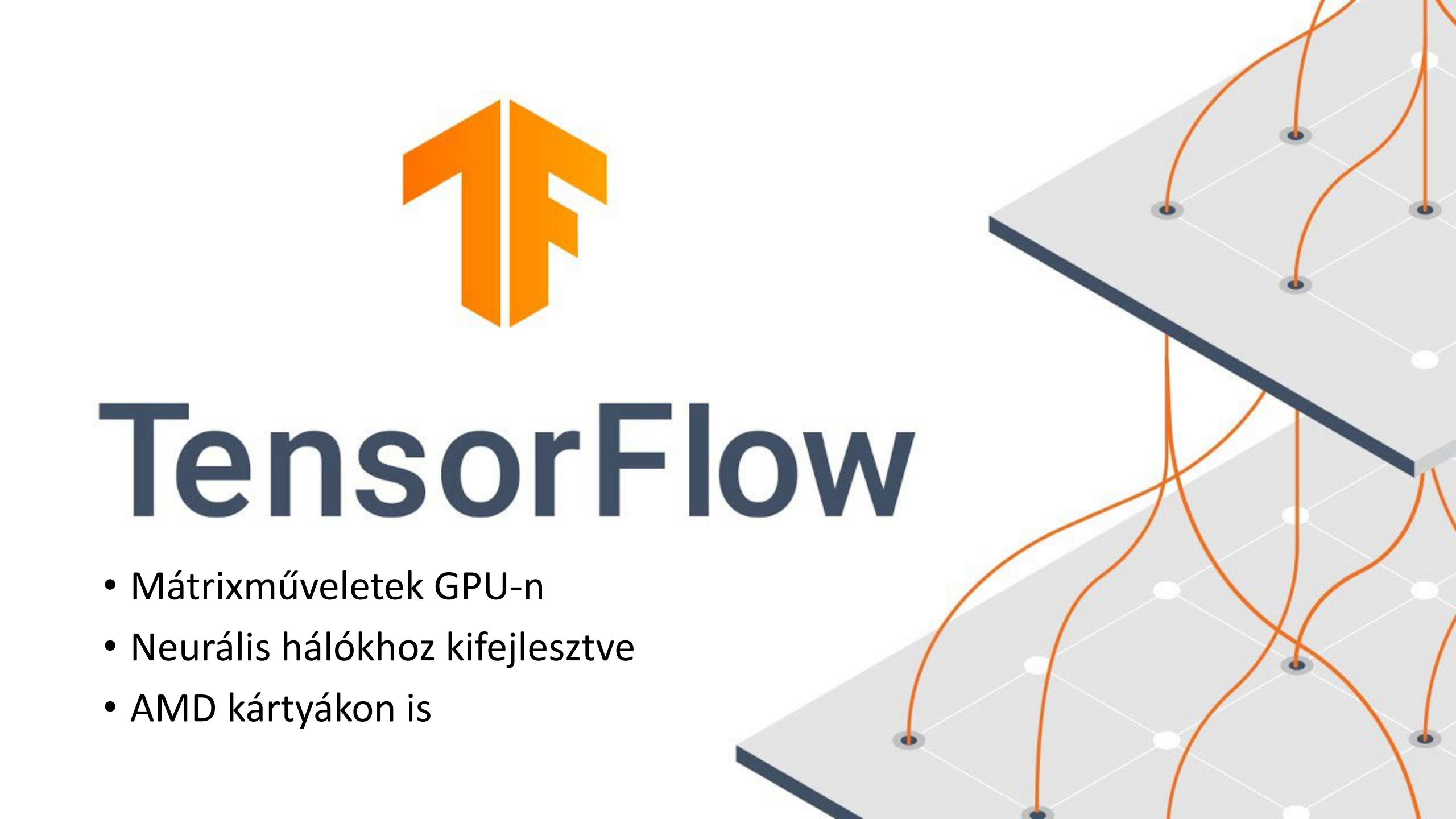
SSD C (512 GB)

SSD D (512 GB)

# GPU

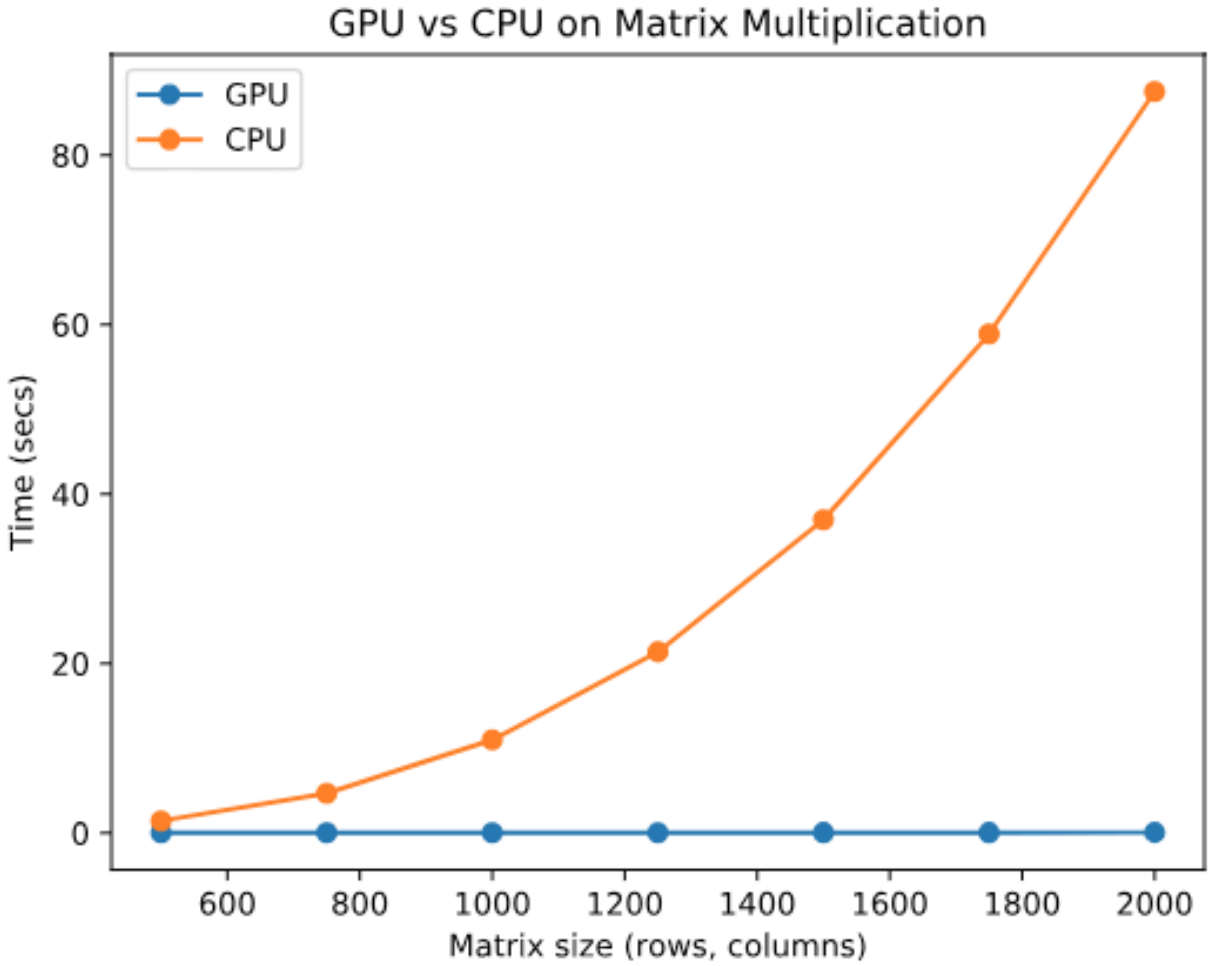
- 3584 CUDA mag

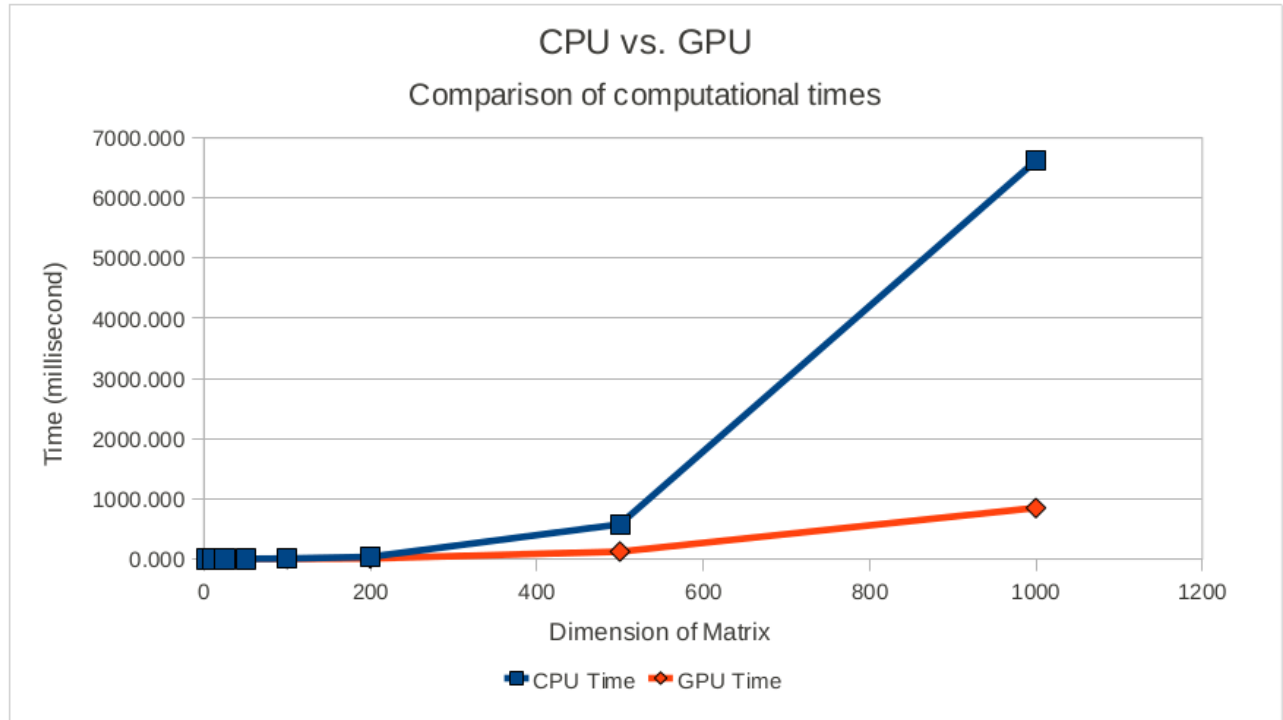
  NVIDIA GeForce RTX 3060
- block_size: min 32 thread
- grid_size: max 112



# TensorFlow

- Mátrixműveletek GPU-n
- Neurális hálókhoz kifejlesztve
- AMD kártyákon is


GPU vs CPU on Matrix Multiplication
GPU
CPU
Time (secs)
0
20
40
60
80
600
800
1000
1200
1400
1600
1800
2000
Matrix size (rows, columns)


CPU vs. GPU
Comparison of computational times
Time (millisecond)
7000.000
6000.000
5000.000
4000.000
3000.000
2000.000
1000.000
0.000
0
200
400
600
800
1000
1200
Dimension of Matrix
CPU Time
GPU Time


Köszönöm a figyelmet