

Pemrosesan Paralel



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FAKULTAS ILMU KOMPUTER
UNIVERSITAS SRIWIJAYA
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Install net-tools untuk cek IP, vim untuk teks editor.

```
zahrans@zahrans-VirtualBox:~$ sudo apt install net-tools vim
[sudo] password for zahrans:
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
net-tools is already the newest version (1.60+git20181103.0eebece-1ubuntu5).
Suggested packages:
  ctags vim-doc vim-scripts
The following NEW packages will be installed:
  vim vim-runtime
0 upgraded, 2 newly installed, 0 to remove and 0 not upgraded.
Need to get 8.568 kB of archives.
After this operation, 37,6 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 vim-runtime all
2:8.2.3995-1ubuntu2.13 [6.834 kB]
Get:2 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 vim amd64 2:8.2.
3995-1ubuntu2.13 [1.734 kB]
Fetched 8.568 kB in 8s (1.134 kB/s)
Selecting previously unselected package vim-runtime.
[Reading database ... 85%
```

Salin kode cloudmesh-mpi dari github ke linux

```
zahrans@zahrans-VirtualBox:~$ git clone https://github.com/cloudmesh/cloudmesh-mpi.git
Cloning into 'cloudmesh-mpi'...
remote: Enumerating objects: 9875, done.
remote: Counting objects: 100% (9875/9875), done.
remote: Compressing objects: 100% (2145/2145), done.
Receiving objects: 75% (7407/9875), 20.72 MiB | 5.12 MiB/s
```

Kemudian install virtual environment pada linux

```
zahrans@zahrans-VirtualBox:~$ sudo apt install python3.10 python3.10-dev python3
-dev python3.10-venv
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
python3.10 is already the newest version (3.10.12-1~22.04.2).
The following additional packages will be installed:
  javascript-common libexpat1-dev libjs-jquery libjs-sphinxdoc
  libjs-underscore libpython3-dev libpython3.10-dev python3-distutils
  python3-lib2to3 python3-pip-whl python3-setuptools-whl zlib1g-dev
Suggested packages:
  apache2 | lighttpd | httpd
The following NEW packages will be installed:
  javascript-common libexpat1-dev libjs-jquery libjs-sphinxdoc
  libjs-underscore libpython3-dev libpython3.10-dev python3-dev
  python3-distutils python3-lib2to3 python3-pip-whl python3-setuptools-whl
  python3.10-dev python3.10-venv zlib1g-dev
0 upgraded, 15 newly installed, 0 to remove and 0 not upgraded.
Need to get 8.888 kB of archives.
After this operation, 28,5 MB of additional disk space will be used.
Do you want to continue? [Y/n]
```

Lalu membuat virtual environment nya dan menghitung jumlah cpu

```
zahrans@zahrans-VirtualBox:~$ python3 -m venv ~/env3
zahrans@zahrans-VirtualBox:~$ source env3/bin/activate
(env3) zahrans@zahrans-VirtualBox:~$ nano cpu.py
```

```
zahrans@zahrans-VirtualBox: ~
File Edit View Search Terminal Help
GNU nano 6.2      cpu.py *
import multiprocessing
multiprocessing.cpu_count()

zahrans@zahrans-VirtualBox:~$ python3 -m venv ~/env3
zahrans@zahrans-VirtualBox:~$ source env3/bin/activate
(env3) zahrans@zahrans-VirtualBox:~$ nano cpu.py
(env3) zahrans@zahrans-VirtualBox:~$ python -c "import multiprocessing; print(mu
ltiprocessing.cpu_count())"
1
```

Setelah itu install mpi4py

```
(env3) zahrans@zahrans-VirtualBox:~$ pip install mpi4py -U
Collecting mpi4py
  Using cached mpi4py-3.1.5.tar.gz (2.5 MB)
  Installing build dependencies ... done
  Getting requirements to build wheel ... done
  Preparing metadata (pyproject.toml) ... done
Building wheels for collected packages: mpi4py
  Building wheel for mpi4py (pyproject.toml) ... /
```

Buat file count.py

```
zahrans@zahrans-VirtualBox: ~
File Edit View Search Terminal Help
zahrans@zahrans-VirtualBox:~$ source env3/bin/activate
(env3) zahrans@zahrans-VirtualBox:~$ nano count.py
```

Isi dari file count.py

```
zahrans@zahrans-VirtualBox: ~
File Edit View Search Terminal Help
GNU nano 6.2      count.py
import os
import random
from mpi4py import MPI
# Get the input values or set them to a default
n = int(os.environ.get("N") or 20)
max_number = int(os.environ.get("MAX") or 10)
find = int(os.environ.get("FIND") or 8)

comm = MPI.COMM_WORLD # Communicator
size = comm.Get_size() # Number of processes
rank = comm.Get_rank() # Rank of this process

# Each process gets different data, depending on its rank number
data = []
for i in range(n):
    r = random.randint(1, max_number)
    data.append(r)
count = data.count(find)

print(rank, count, data) # Print data from each process

[ Read 20 lines ]
^G Help      ^O Write Out ^W Where Is  ^K Cut       ^T Execute   ^C Location
^X Exit      ^R Read File ^\ Replace   ^U Paste     ^J Justify   ^_ Go To Line
```

Hasil dari perhitungan

```
zahrans@zahrans-VirtualBox: ~  
File Edit View Search Terminal Help  
zahrans@zahrans-VirtualBox:~$ source env3/bin/activate  
(env3) zahrans@zahrans-VirtualBox:~$ nano count.py  
(env3) zahrans@zahrans-VirtualBox:~$ nano count.py  
(env3) zahrans@zahrans-VirtualBox:~$ mpiexec -n 4 python count.py  
3 4 [8, 8, 10, 8, 5, 9, 9, 5, 9, 7, 3, 6, 7, 8, 4, 10, 5, 7, 6, 10]  
2 1 [9, 7, 5, 8, 1, 1, 9, 7, 4, 10, 5, 1, 9, 6, 2, 4, 9, 5, 6, 2]  
0 2 [3, 3, 3, 2, 9, 10, 2, 1, 10, 10, 9, 7, 10, 8, 1, 8, 5, 1, 2, 10]  
1 2 [8, 5, 5, 7, 10, 7, 1, 4, 3, 8, 2, 6, 5, 4, 3, 10, 10, 5, 5, 5]  
(env3) zahrans@zahrans-VirtualBox:~$
```

MPI

Cek IP Pada Server dan Client

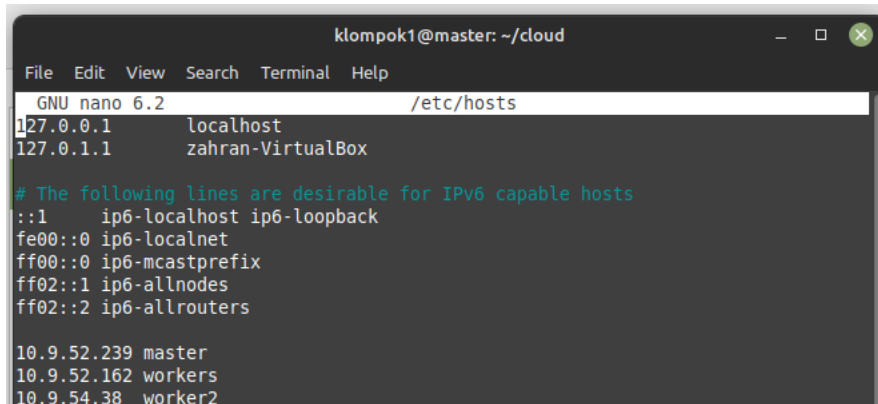
```
zahrans@master: ~  
File Edit View Search Terminal Help  
zahrans@master:~$ ifconfig  
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500  
    inet 192.168.1.6 netmask 255.255.255.0 broadcast 192.168.1.255  
    inet6 fe80::4ba7:6889:a5b0:a40c prefixlen 64 scopeid 0x20<link>  
    ether 08:00:27:f8:06:4e txqueuelen 1000 (Ethernet)  
    RX packets 282 bytes 35292 (35.2 KB)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 154 bytes 16500 (16.5 KB)  
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0  
  
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536  
    inet 127.0.0.1 netmask 255.0.0.0  
    inet6 ::1 prefixlen 128 scopeid 0x10<host>  
    loop txqueuelen 1000 (Local Loopback)  
    RX packets 116 bytes 9678 (9.6 KB)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 116 bytes 9678 (9.6 KB)  
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

```
zahrans@workers: ~  
File Edit View Search Terminal Help  
zahrans@workers:~$ ifconfig  
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500  
    inet 192.168.1.7 netmask 255.255.255.0 broadcast 192.168.1.255  
    inet6 fe80::c5db:6ec4:5d6e:eb84 prefixlen 64 scopeid 0x20<link>  
    ether 08:00:27:6d:30:6f txqueuelen 1000 (Ethernet)  
    RX packets 252 bytes 30759 (30.7 KB)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 147 bytes 15910 (15.9 KB)  
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0  
  
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536  
    inet 127.0.0.1 netmask 255.0.0.0  
    inet6 ::1 prefixlen 128 scopeid 0x10<host>  
    loop txqueuelen 1000 (Local Loopback)  
    RX packets 113 bytes 9519 (9.5 KB)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 113 bytes 9519 (9.5 KB)  
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Buka file /etc/hosts

```
zahrn@master:~$ sudo nano /etc/hosts
```

tambahkan isinya dengan IP Server dan Client



```
klompok1@master: ~/cloud
GNU nano 6.2 /etc/hosts
127.0.0.1 localhost
127.0.1.1 zahrn-VirtualBox

# The following lines are desirable for IPv6 capable hosts
::1 ip6-localhost ip6-loopback
fe00::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters

10.9.52.239 master
10.9.52.162 workers
10.9.54.38 worker2
```

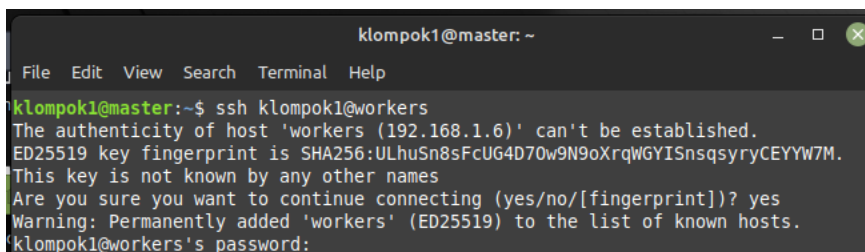
Buat user baru di Server dan Client

```
zahrn@master:~$ sudo adduser klompok1
```

Beri akses root dan masuk ke user kemudian install ssh

```
zahrn@master:~$ sudo usermod -aG sudo klompok1
```

Hubungkan Server dan Client



```
klompok1@master: ~
File Edit View Search Terminal Help
klompok1@master:~$ ssh klompok1@workers
The authenticity of host 'workers (192.168.1.6)' can't be established.
ED25519 key fingerprint is SHA256:ULhuSn8sFcUG4D70w9N9oXrqWGYISnsqsyryCEYYW7M.
This key is not known by any other names
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added 'workers' (ED25519) to the list of known hosts.
klompok1@workers's password:
```

Lakukan hal yang sama pada worker

```
klompok1@workers:~$ sudo apt install openssh-server
[sudo] password for klompok1:
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
openssh-server is already the newest version (1:8.9p1-3ubuntu0.4).
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
```

Generate keygen pada server

```
klompok1@master:~$ ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/home/klompok1/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/klompok1/.ssh/id_rsa
Your public key has been saved in /home/klompok1/.ssh/id_rsa.pub
The key fingerprint is:
SHA256:hg4ITUw8Zq0VwYN8Ezb1tqywsMczqI1QkydU/w75gHw klompok1@master
The key's randomart image is:
+---[RSA 3072]-----+
|  =o+B=.      |
|  o0oBo .    |
| .oo= o. o    |
|  o.+ . = .   |
|   * = E S    |
| . + + * .    |
| .   oo. +    |
| .  o.=.      |
|  o.o.oo      |
+---[SHA256]-----+
```

Copy key pubic ke client pada server kemudian buat shared folder dan install NFS Server

```
klompok1@master: ~
File Edit View Search Terminal Help
klompok1@master:~$ cd .ssh
klompok1@master:~/.ssh$ cat id_rsa.pub | ssh klompok1@master "mkdir .ssh; cat >>
.ssh/authorized_keys"
klompok1@master's password:
mkdir: cannot create directory '.ssh': File exists
klompok1@master:~/.ssh$ cd
klompok1@master:~$ mkdir cloud
klompok1@master:~$ sudo apt install nfs-kernel-server
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following NEW packages will be installed:
  nfs-kernel-server
0 upgraded, 1 newly installed, 0 to remove and 43 not upgraded.
Need to get 140 kB of archives.
After this operation, 526 kB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 nfs-kernel-server amd64 1:2.6.1-1ubuntu1.2 [140 kB]
Fetched 140 kB in 2s (68,1 kB/s)
Selecting previously unselected package nfs-kernel-server.
(Reading database ... 332992 files and directories currently installed.)
Preparing to unpack .../nfs-kernel-server_1%3a2.6.1-1ubuntu1.2_amd64.deb ...
Unpacking nfs-kernel-server (1:2.6.1-1ubuntu1.2) ...
Setting up nfs-kernel-server (1:2.6.1-1ubuntu1.2) ...
```

Buat shared folder pada Server dan Client serta lakukan install NFS Server pada Server

```
klompok1@master:~$ mkdir cloud
klompok1@master:~$ sudo apt install nfs-kernel-server
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following NEW packages will be installed:
  nfs-kernel-server
0 upgraded, 1 newly installed, 0 to remove and 43 not upgraded.
Need to get 140 kB of archives.
After this operation, 526 kB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 nfs-kernel-server amd64 1:2.6.1-1ubuntu1.2 [140 kB]
Fetched 140 kB in 2s (68,1 kB/s)
Selecting previously unselected package nfs-kernel-server.
(Reading database ... 332992 files and directories currently installed.)
Preparing to unpack .../nfs-kernel-server_1%3a2.6.1-1ubuntu1.2_amd64.deb ...
Unpacking nfs-kernel-server (1:2.6.1-1ubuntu1.2) ...
Setting up nfs-kernel-server (1:2.6.1-1ubuntu1.2) ...
```

```
klompok1@workers:~$ mkdir cloud
klompok1@workers:~$ sudo apt install nfs-common
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
nfs-common is already the newest version (1:2.6.1-1ubuntu1.2).
0 upgraded, 0 newly installed, 0 to remove and 5 not upgraded.
```

Konfigurasi file /etc/exports pada server

```
klompok1@master:~$ sudo nano /etc/exports
```

```
klompok1@master: ~
File Edit View Search Terminal Help
GNU nano 6.2 /etc/exports
# /etc/exports: the access control list for filesystems which may be exported
# to NFS clients. See exports(5).
#
# Example for NFSv2 and NFSv3:
# /srv/homes hostname1(rw,sync,no_subtree_check) hostname2(ro,sync,no_subtree_check)
#
# Example for NFSv4:
# /srv/nfs4 gss/krb5i(rw,sync,fsid=0,crossmnt,no_subtree_check)
# /srv/nfs4/homes gss/krb5i(rw,sync,no_subtree_check)
#
/home/klompok1/cloud *(rw,sync,no_root_squash,no_subtree_check)

[ Read 12 lines ]
^G Help ^O Write Out ^W Where Is ^K Cut ^T Execute ^C Location
^X Exit ^R Read File ^N Replace ^U Paste ^J Justify ^_ Go To Line
```

Selanjutnya ketikkan perintah berikut

```
klompok1@master: ~
File Edit View Search Terminal Help
klompok1@master:~$ sudo exportfs -a
klompok1@master:~$ sudo systemctl restart nfs-kernel-server
```

Mounting pada Client lalu install MPI pada Server dan Client

```
klompok1@workers: ~/cloud
File Edit View Search Terminal Help
klompok1@workers:~$ sudo mount master:/home/klompok1/cloud /home/klompok1/cloud
klompok1@workers:~$ sudo apt install openmpi-bin libopenmpi-dev
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
libopenmpi-dev is already the newest version (4.1.2-2ubuntu1).
openmpi-bin is already the newest version (4.1.2-2ubuntu1).
0 upgraded, 0 newly installed, 0 to remove and 5 not upgraded.
```

Lakukan testing di server Buat file touch.py

```
klompok1@master:~/cloud$ touch test.py
klompok1@master:~/cloud$ ls
test.py
```

Edit barisnya dengan print("Hello World")

```
klompok1@master: ~/cloud
File Edit View Search Terminal Help
GNU nano 6.2 test.py
print("Hello World")
```

Jalankan file menggunakan MPI

```
klompok1@master:~/cloud$ mpirun -np 1 python3 test.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Hello World
```

Buat file bubblesort.py

```
klompok1@master:~/cloud$ sudo nano bubblesort.py
```

Mengisi file dengan kode berikut

```
klompok1@master: ~/cloud
File Edit View Search Terminal Help
GNU nano 6.2 bubblesort.py
from mpi4py import MPI
import time

start=time.time()

def bubble_sort_parallel(data):
    comm = MPI.COMM_WORLD
    rank = comm.Get_rank()
    size = comm.Get_size()

    local_data = data[rank::size]
    local_data.sort()

    for step in range(1, size):
        if rank % 2 == 0:
            if rank < size - 1:
                comm.send(local_data, dest=rank+1)
                received_data = comm.recv(source=rank+1)
                local_data = merge(local_data, received_data)
            else:
                Read 63 lines
                Execute
                Location
```

```
klompok1@master: ~/cloud
File Edit View Search Terminal Help
GNU nano 6.2 bubblesort.py

def merge_sorted_arrays(arrays):
    merged_array = []
    for array in arrays:
        merged_array = merge(merged_array, array)
    return merged_array

if __name__ == "__main__":
    data = [5, 2, 9, 1, 5, 6]
    comm = MPI.COMM_WORLD
    rank = comm.Get_rank()

    if rank == 0:
        sorted_data = bubble_sort_parallel(data)
        print("Sorted Data:", sorted_data)
    else:
        bubble_sort_parallel(data)

end=time.time()
print("waktu dikerjakan",end-start)
```



```

GNU nano 6.2 bubblesort.py
sorted_data = comm.gather(local_data, root=0)
if rank == 0:
    sorted_data = merge_sorted_arrays(sorted_data)
    return sorted_data
else:
    return None

def merge(arr1, arr2):
    merged_array = []
    i = j = 0
    while i < len(arr1) and j < len(arr2):
        if arr1[i] < arr2[j]:
            merged_array.append(arr1[i])
            i += 1
        else:
            merged_array.append(arr2[j])
            j += 1
    merged_array.extend(arr1[i:])
    merged_array.extend(arr2[j:])
    return merged_array

```

Jalankan file bubblesort.py Menggunakan MPI

```

waktu dikerjakan 0.00029020107190097
klompok1@master:~/cloud$ mpirun -np 1 -host master,worker2,worker3 python3 bubblesort.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Sorted Data: [1, 2, 5, 5, 6, 9]
waktu dikerjakan 0.0002734661102294922

```

Jalankan file menggunakan python3 untuk melihat perbandingan kecepatan waktu run nya

```

klompok1@master:~/cloud$ python3 bubblesort.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Sorted Data: [1, 2, 5, 5, 6, 9]
waktu dikerjakan 0.0001671314239501953

```

Membuat file numeric.py

```

klompok1@master:~/cloud$ touch numeric.py

```

```

klompok1@master:~/cloud$ sudo nano numeric.py

```

Mengisi File dengan kode berikut

```
klompok1@master: ~/cloud
File Edit View Search Terminal Help
GNU nano 6.2 numeric.py
from mpi4py import MPI
import numpy as np
import time

start=time.time()

def parallel_sum(data):
    comm = MPI.COMM_WORLD
    rank = comm.Get_rank()
    size = comm.Get_size()

    # Bagi data di antara proses
    local_data = np.array_split(data, size)[rank]

    # Hitung jumlah lokal
    local_sum = np.sum(local_data)

    # Gather hasil dari setiap proses
    total_sum = comm.reduce(local_sum, op=MPI.SUM, root=0)

[ Read 31 lines ]
^G Help      ^O Write Out ^W Where Is  ^K Cut       ^T Execute   ^C Location
^X Exit      ^R Read File ^\ Replace   ^U Paste     ^J Justify   ^_ Go To Line
```

```
    # Gather hasil dari setiap proses
    total_sum = comm.reduce(local_sum, op=MPI.SUM, root=0)

    if rank == 0:
        print("Total sum:", total_sum)

if __name__ == '__main__':
    # Data numerik (gunakan data sesuai kebutuhan Anda)
    data = np.array([1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12])

    # Panggil fungsi untuk menjalankan program secara paralel
    parallel_sum(data)
end=time.time()
print("Waktu dikerjakan",end-start)
```

Jalankan file numeric.py Menggunakan MPI

```
klompok1@master: ~/cloud$ sudo nano bubblesort.py
klompok1@master:~/cloud$ mpirun -np 1 -host master,workers,worker2,worker3 python3 bubblesort.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Sorted Data: [1, 2, 5, 5, 6, 9]
waktu dikerjakan 0.0002205371856689453
```

Jalankan menggunakan python3 untuk melihat perbandingan waktu kecepatan run nya

```
klompok1@master:~/cloud$ python3 bubblesort.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Sorted Data: [1, 2, 5, 5, 6, 9]
waktu dikerjakan 0.0002448558807373047
```