LAPORAN PEMROSESAN PARALEL

(Numerik Python Menggunakan MPI Secara Paralel)

Disusun Oleh:

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FAKULTAS ILMU KOMPUTER

PROGRAM STUDI SISTEM KOMPUTER

UNIVERSITAS SRIWIJAYA

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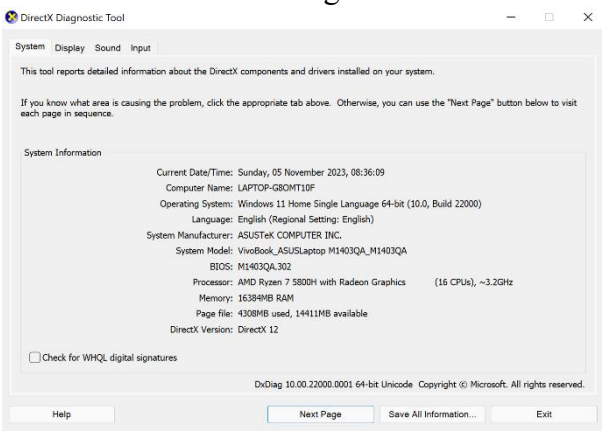
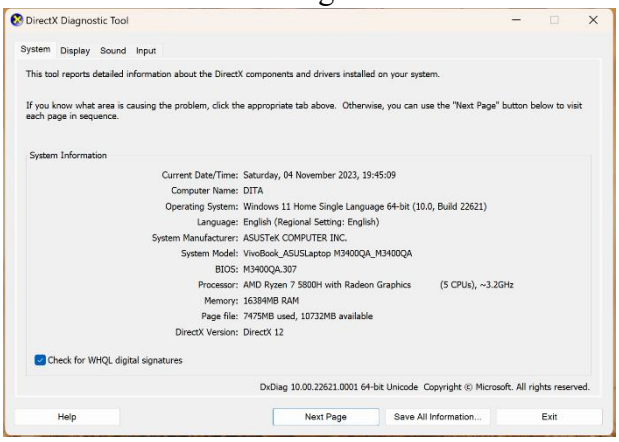
1. **Master dan Worker**

   Menentukan master dan worker dengan melihat spesifikasi masing masing device

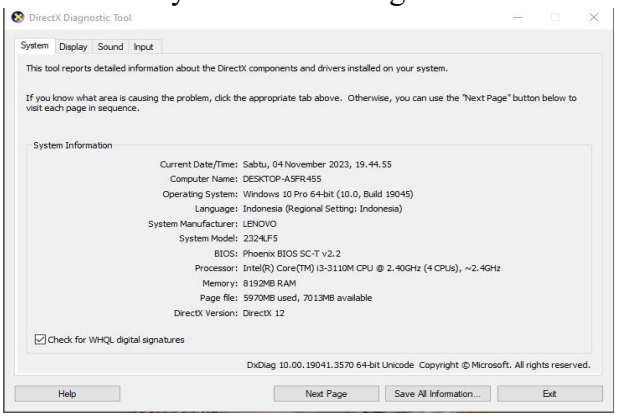
   - Khairunnisa Junaidi sebagai **master**



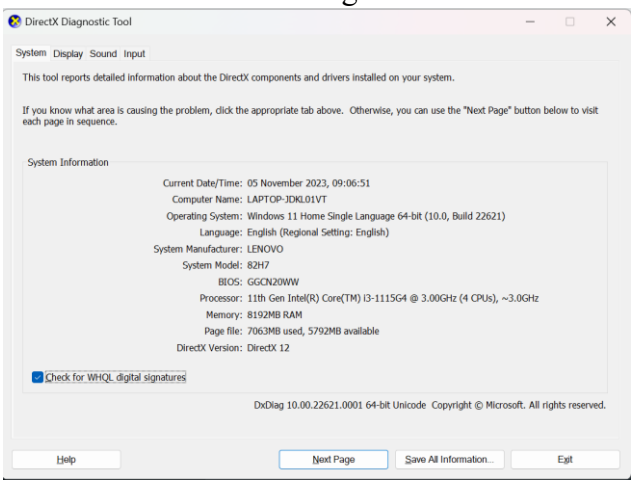
   - Eka Ratna Anindita sebagai **worker1**



   - Almirah Callysta Aurelie sebagai **worker2**



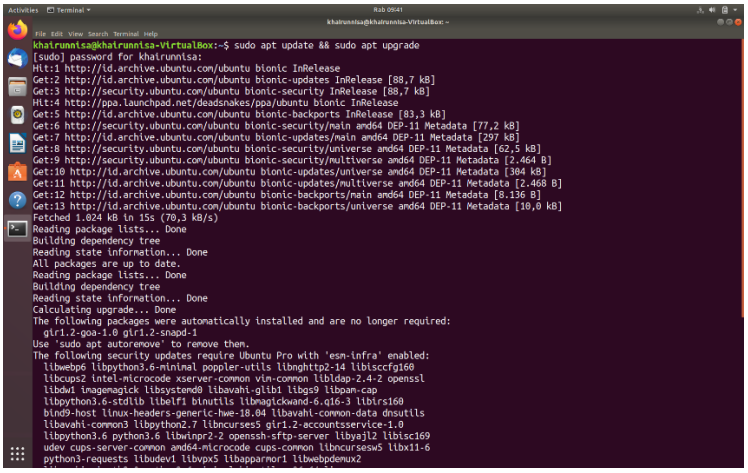
- Nabilla Suci Febriani sebagai **worker3**



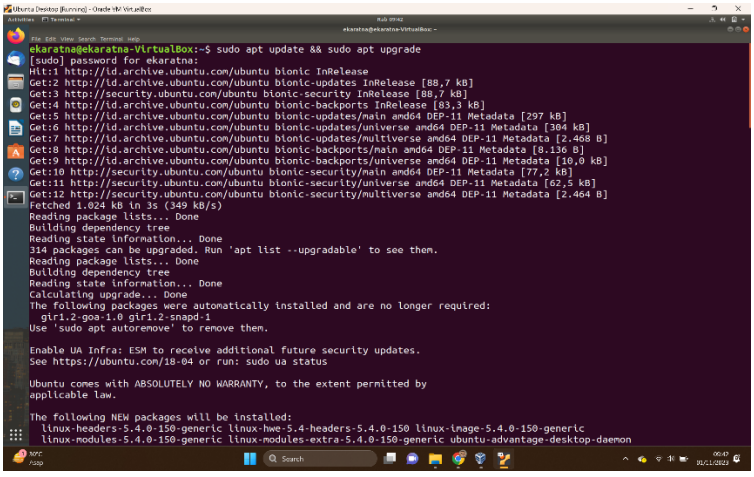
2. Upgrade OS

Menggunakan command ***'sudo apt update && sudo apt upgrade'*** untuk memperbarui OS pada setiap device

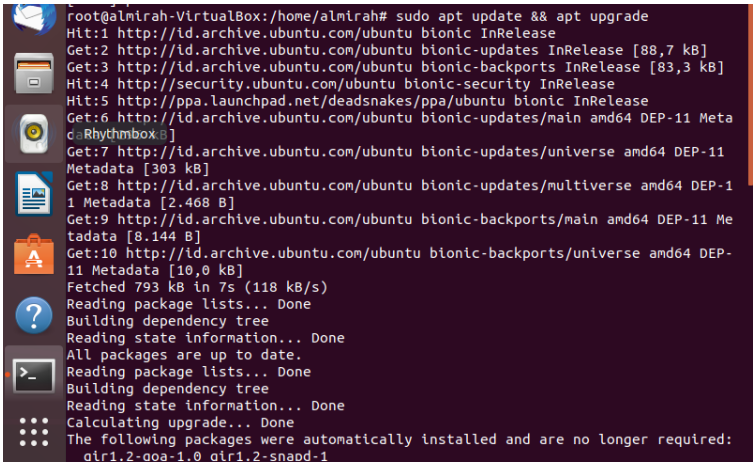
- Master



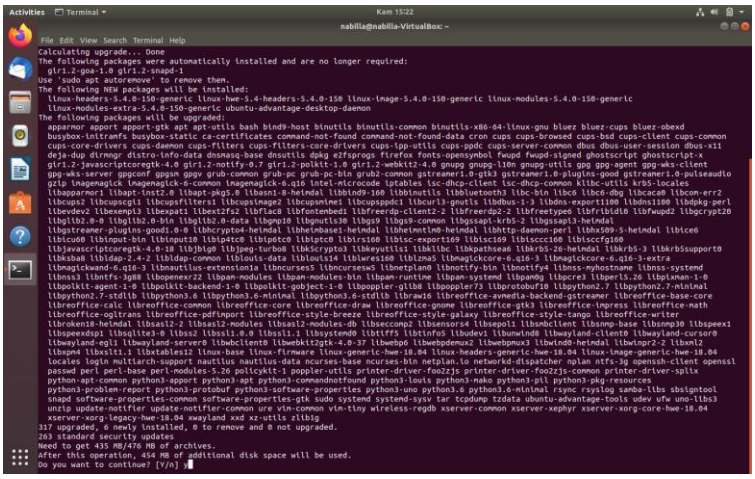
- Worker1



- Worker2



- Worker3



3. **Install net-tools**
   Melakukan penginstalan net-tools dengan menggunakan command ***'sudo apt install net-tools vim'*** untuk cek IP, vim sebagai teks editor

```
root@almirah-VirtualBox:/home/almirah# sudo apt install net-tools vim
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  vim-runtime
Suggested packages:
  ctags vim-doc vim-scripts
The following NEW packages will be installed:
  net-tools vim vim-runtime
0 upgraded, 3 newly installed, 0 to remove and 0 not upgraded.
Need to get 6.790 kB of archives.
After this operation, 32,8 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu bionic/main amd64 net-tools amd64 1.6
0+git20161116.90da8a0-1ubuntu1 [194 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 vim-runtime
 all 2:8.0.1453-1ubuntu1.13 [5.439 kB]
Get:3 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 vim amd64 2
:8.0.1453-1ubuntu1.13 [1.156 kB]
Fetched 6.790 kB in 12s (544 kB/s)
Selecting previously unselected package net-tools.
(Reading database ... 164777 files and directories currently installed.)
Preparing to unpack .../net-tools_1.60+git20161116.90da8a0-1ubuntu1_amd64.deb .
..
Unpacking net-tools (1.60+git20161116.90da8a0-1ubuntu1) ...
```

4. **Konfigurasi file**
   Membuka file /etc/hosts menggunakan command ***'sudo nano /etc/hosts'***

```
khairunnisa@khairunnisa-VirtualBox:~$ sudo nano /etc/hosts
```

Lalu mengedit file dengan menambahkan IP dan peran.

```
                                dina@worker2: ~
File  Edit  View  Search  Terminal  Help
  GNU nano 2.9.3                        /etc/hosts

10.1.40.26      worker2 localhost
127.0.1.1        almirah-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

10.1.40.16       master
10.1.42.182      worker1
10.1.43.181      worker3
```

5. **Konfigurasi SSH**

   Melakukan konfigurasi SSH, SSH(Secure Shell) digunakan untuk otentikasi dan pertukaran data aman antara node dalam cluster MPI.

- **Install SSH**

  Melakukan penginstallan SSH dengan command ***'sudo apt install openssh-server'***

```
dina@almirah-VirtualBox:/home/almirah$ sudo apt install openssh-server
[sudo] password for dina:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  ncurses-term openssh-sftp-server ssh-import-id
Suggested packages:
  molly-guard monkeysphere rssh ssh-askpass
The following NEW packages will be installed:
  ncurses-term openssh-server openssh-sftp-server ssh-import-id
0 upgraded, 4 newly installed, 0 to remove and 0 not upgraded.
Need to get 637 kB of archives.
After this operation, 5.320 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 ncurses-ter
m all 6.1-1ubuntu1.18.04.1 [248 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 openssh-sft
p-server amd64 1:7.6p1-4ubuntu0.7 [45.5 kB]
```

Dapat dilakukan pengecekan SSH untuk menghubungkan master ke klien, dengan command ***'ssh <nama user>@<host>'***

```
dina@ekaratna-VirtualBox:~$ ssh dina@master
The authenticity of host 'master (192.168.100.142)' can't be established.
ECDSA key fingerprint is SHA256:Lmn8CRoRcOUPvq0NnBUvxTJ4eQxhxy6BrkQurtwAx1I.
Are you sure you want to continue connecting (yes/no)? y
Please type 'yes' or 'no': yes
Warning: Permanently added 'master,192.168.100.142' (ECDSA) to the list of known hosts.
dina@master's password:
Welcome to Ubuntu 18.04.6 LTS (GNU/Linux 5.4.0-150-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

Expanded Security Maintenance for Infrastructure is not enabled.

0 updates can be applied immediately.

130 additional security updates can be applied with ESM Infra.
Learn more about enabling ESM Infra service for Ubuntu 18.04 at
https://ubuntu.com/18-04

New release '20.04.6 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Your Hardware Enablement Stack (HWE) is supported until April 2023.
Last login: Thu Nov  2 16:02:39 2023 from 192.168.100.145
To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.

dina@khairunnisa-VirtualBox:~$
```

- **Generate keygen**

  Dilakukan di master, menggunakan command ***'ssh-keygen –t rsa'***

```
dina@khairunnisa-VirtualBox:~$ ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/home/dina/.ssh/id_rsa):
Created directory '/home/dina/.ssh'.
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/dina/.ssh/id_rsa.
Your public key has been saved in /home/dina/.ssh/id_rsa.pub.
The key fingerprint is:
SHA256:3ost3qLxcWz3i13VyuVaV+aOw7nfFscE+P3TtQrETWQ dina@khairunnisa-VirtualBox
The key's randomart image is:
+---[RSA 2048]----+
|            .E   |
|           o..   |
|          . o. o |
|           o .. =|
|        S .    o@|
|       . o . . XB|
|      . o = o.+.X|
|       ooB o =+*+|
|      .o+o+ . B*+|
+----[SHA256]-----+
```

- **Input key publik ke klient**

  Dilakukan di master, membuat isi dari file *id_rsa.pub* disalin ke file *authorized_keys* menggunakan command ***'cd .ssh'***

```
dina@khairunnisa-VirtualBox:~$ cd .ssh
```

  - **Master – worker1**

```
dina@khairunnisa-VirtualBox:~/.ssh$ cat id_rsa.pub | ssh dina@worker1 " cat>> .ssh/authorized_keys"
```

```
dina@ekaratna-VirtualBox:~$ ls .ssh
authorized_keys  known_hosts
```

  - **Master – worker2**

```
dina@khairunnisa-VirtualBox:~/.ssh$ cat id_rsa.pub | ssh dina@worker2 " cat>> .ssh/authorized_keys"
```

```
dina@almirah-VirtualBox:~$ ls .ssh
authorized_keys  known_hosts
```

  - **Master – worker3**

```
dina@khairunnisa-VirtualBox:~/.ssh$ cat id_rsa.pub | ssh dina@worker3 " cat>> .ssh/authorized_keys"
```

```
dina@nabilla-VirtualBox:~$ ls .ssh
authorized_keys  known_hosts
```

6. **Konfigurasi NFS**

Konfigurasi NFS (Network File System) merupakan proses mengatur dan mengkonfigurasi sistem berkas yang memungkinkan berbagi sistem berkas antara komputer dalam jaringan.

- **Shared folder**

Membuat folder bersama menggunakan command ***'mkdir <nama folder>'***

```
dina@nabilla-VirtualBox:~$ mkdir pempar
dina@nabilla-VirtualBox:~$
```

- **Install NFS Server**

Menginstall NFS pada master dengan command ***'sudo apt install nfs-kernel-server'***

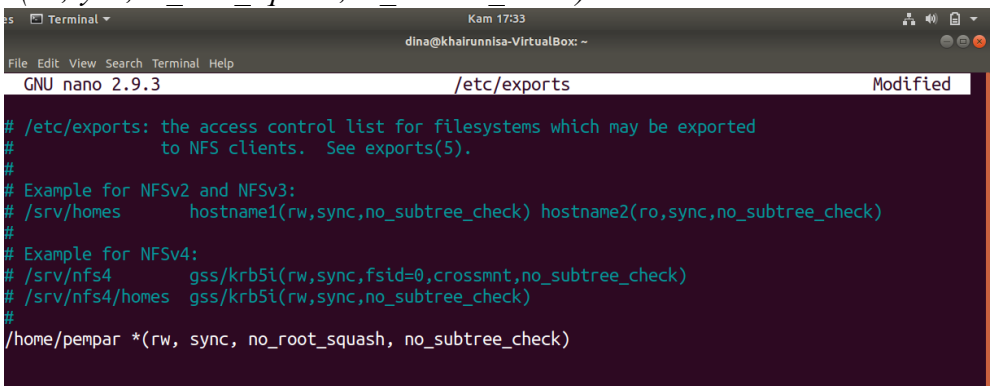
```
dina@khairunnisa-VirtualBox:~$ sudo apt install nfs-kernel-server
[sudo] password for dina:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  keyutils libnfsidmap2 libtirpc1 nfs-common rpcbind
Suggested packages:
  open-iscsi watchdog
The following NEW packages will be installed:
  keyutils libnfsidmap2 libtirpc1 nfs-common nfs-kernel-server rpcbind
0 upgraded, 6 newly installed, 0 to remove and 0 not upgraded.
Need to get 492 kB of archives.
After this operation, 1.709 kB of additional disk space will be used.
Do you want to continue? [Y/n]
```

- **Konfigurasi file**

Dilakukan di master, buka file /etc/exports dengan command ***'sudo nano /etc/exports'***

```
dina@khairunnisa-VirtualBox:~$ sudo nano /etc/exports
```

Dan dilakukan pengeditan pada file, dengan menambahkan *<lokasi shared folder> *(rw,sync,no_root_squash,no_subtree_check)*



Lalu, untuk menyimpan ulang daftar direktori setelah mengedit file dapat menggunakan command ***'sudo exportfs –a'*** dan untuk memulai ulang layanan pada server dapat menggunakan command ***'sudo systemctl restart nfs-kernel-server'***

```
dina@khairunnisa-VirtualBox:~$ sudo exportfs -a
dina@khairunnisa-VirtualBox:~$ sudo systemctl restart nfs-kernel-server
```

- **Install NFS Klient**

Melakukan instalasi NFS pada worker dengan command ***'sudo apt install nfs-common'***

- Worker1

```
dina@ekaratna-VirtualBox:~$ sudo apt install nfs-common
Reading package lists... Done
Building dependency tree
Reading state information... Done
nfs-common is already the newest version (1:1.3.4-2.1ubuntu5.5).
nfs-common set to manually installed.
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
```

- Worker2

```
dina@almirah-VirtualBox:~$ sudo apt install nfs-common
[sudo] password for dina:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  keyutils libnfsidmap2 libtirpc1 rpcbind
Suggested packages:
  open-iscsi watchdog
The following NEW packages will be installed:
  keyutils libnfsidmap2 libtirpc1 nfs-common rpcbind
0 upgraded, 5 newly installed, 0 to remove and 0 not upgraded.
Need to get 399 kB of archives.
After this operation, 1.364 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 keyutils am
d64 1.5.9-9.2ubuntu2.1 [48,1 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu bionic/main amd64 libnfsidmap2 amd64
0.25-5.1 [27,2 kB]
Get:3 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtirpc1 a
md64 0.2.5-1.2ubuntu0.1 [75,7 kB]
Get:4 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 rpcbind amd
64 0.2.3-0.6ubuntu0.18.04.4 [42,1 kB]
Get:5 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 nfs-common
```

- Worker3

```
dina@nabilla-VirtualBox:~$ sudo apt install nfs-common
Reading package lists... Done
Building dependency tree
Reading state information... Done
nfs-common is already the newest version (1:1.3.4-2.1ubuntu5.5).
nfs-common set to manually installed.
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
```

➢ **Mounting**

Dilakukan pada worker dengan menggunakan command ***'sudo mount <server host>:<lokasi shared folder di server> <lokasi shared folder di client>'***

- Worker1

```
dina@ekaratna-VirtualBox:~$ sudo mkdir /home/pempar
dina@ekaratna-VirtualBox:~$ sudo mount master:/home/pempar /home/pempar
```

- Worker2

```
dina@almirah-VirtualBox:~$ sudo mkdir /home/pempar
dina@almirah-VirtualBox:~$ sudo mount master:/home/pempar /home/pempar
```

- Worker3

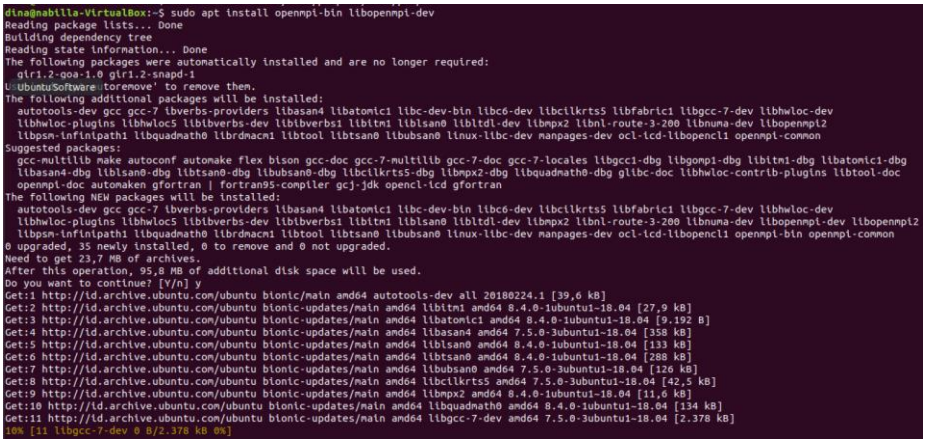
```
dina@nabilla-VirtualBox:~$ sudo mkdir /home/pempar
dina@nabilla-VirtualBox:~$ sudo mount master:/home/pempar /home/pempar
```

7. MPI

MPI adalah singkatan dari "Message Passing Interface." Ini adalah standar komunikasi yang digunakan dalam pemrograman paralel, terutama dalam pemrograman terdistribusi untuk sistem berbasis kluster atau superkomputer.

➢ **Install MPI**

Melakukan instalasi MPI dengan command ***'sudo apt install openmpi-bin libopenmpi-dev'***



- **Testing**

  Dilakukan di master, membuat file python di folder sebelumnya, dengan command ***'touch <nama file>.py'***

```
dina@khairunnisa-VirtualBox:/home/pempar$ sudo chmod -R 777 /home/pempar
dina@khairunnisa-VirtualBox:/home/pempar$ touch test.py
dina@khairunnisa-VirtualBox:/home/pempar$
```

  Lalu, dapat melakukan pengeditan dalam file dengan menggunakan command ***'nano <nama file>.py'***

```
dina@khairunnisa-VirtualBox:/home/pempar$ nano test.py
```

8. **Konfigurasi python**

- **Install python**

  Melakukan instalasi python versi 3 dengan menggunakan command ***'sudo apt install python3-pip'*** dan python versi 2 dengan menggunakan command ***'sudo apt install python-pip'***

```
dina@khairunnisa-VirtualBox:/home/pempar$ sudo apt install python3-pip
[sudo] password for dina:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  build-essential dh-python dpkg-dev fakeroot g++ g++-7 libalgorithm-diff-perl
  libalgorithm-diff-xs-perl libalgorithm-merge-perl libexpat1-dev libfakeroot libpython3-dev
  libpython3.6-dev libstdc++-7-dev make python-pip-whl python3-dev python3-distutils
  python3-lib2to3 python3-setuptools python3-wheel python3.6-dev
Suggested packages:
  debian-keyring g++-multilib g++-7-multilib gcc-7-doc libstdc++6-7-dbg libstdc++-7-doc make-doc
  python-setuptools-doc
The following NEW packages will be installed:
  build-essential dh-python dpkg-dev fakeroot g++ g++-7 libalgorithm-diff-perl
  libalgorithm-diff-xs-perl libalgorithm-merge-perl libexpat1-dev libfakeroot libpython3-dev
  libpython3.6-dev libstdc++-7-dev make python-pip-whl python3-dev python3-distutils
  python3-lib2to3 python3-pip python3-setuptools python3-wheel python3.6-dev
0 upgraded, 23 newly installed, 0 to remove and 0 not upgraded.
Need to get 60,0 MB of archives.
After this operation, 131 MB of additional disk space will be used.
Do you want to continue? [Y/n]
```

```
dina@khairunnisa-VirtualBox:~$ sudo apt install python-pip
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  libpython-all-dev libpython-dev libpython-stdlib libpython2.7-dev python
  python-all python-all-dev python-asn1crypto python-cffi-backend
  python-crypto python-cryptography python-dbus python-dev python-enum34
  python-gi python-idna python-ipaddress python-keyring python-keyrings.alt
  python-minimal python-pkg-resources python-secretstorage python-setuptools
  python-six python-wheel python-xdg python2.7 python2.7-dev python2.7-minimal
Suggested packages:
  python-doc python-tk python-crypto-doc python-cryptography-doc
  python-cryptography-vectors python-dbus-dbg python-dbus-doc
  python-enum34-doc python-gi-cairo libkf5wallet-bin gir1.2-gnomekeyring-1.0
  python-fs python-gdata python-keyczar python-secretstorage-doc
  python-setuptools-doc python2.7-doc binfmt-support
The following NEW packages will be installed:
  libpython-all-dev libpython-dev libpython-stdlib libpython2.7-dev python
  python-all python-all-dev python-asn1crypto python-cffi-backend
  python-crypto python-cryptography python-dbus python-dev python-enum34
  python-gi python-idna python-ipaddress python-keyring python-keyrings.alt
  python-minimal python-pip python-pkg-resources python-secretstorage
  python-setuptools python-six python-wheel python-xdg python2.7 python2.7-dev
  python2.7-minimal
0 upgraded, 30 newly installed, 0 to remove and 0 not upgraded.
Need to get 30,5 MB/32,1 MB of archives.
After this operation, 55,8 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu bionic/main amd64 python amd64 2.7.15~rc1-1 [140 kB]
```

- **Install pustaka MPI4**

  Melakukan instalasi pustaka MPI4 yang menyediakan dukungan untuk komunikasi dan pemrograman paralel menggunakan MPI (Message Passing Interface) dapat dilakukan dengan command ***'pip install mpi4py'***

```
dina@khairunnisa-VirtualBox:~$ pip install mpi4py
Collecting mpi4py
  Downloading https://files.pythonhosted.org/packages/2e/1a/1393e69df9cf7b04143a51776727dd048586781
bca82543594ab439e2eb4/mpi4py-3.1.5.tar.gz (2.5MB)
    100% |████████████████████████████████| 2.5MB 280kB/s
Building wheels for collected packages: mpi4py
  Running setup.py bdist_wheel for mpi4py ... |
done
  Stored in directory: /home/dina/.cache/pip/wheels/6a/a2/4d/68998a0c10a3a307e55777b41b3da359a4742f
087eff53acce
Successfully built mpi4py
Installing collected packages: mpi4py
Successfully installed mpi4py-3.1.5
```

- **Input kunci**

  Dilakukan oleh master untuk menyalin kunci publik SSH ke mesin worker sehingga master dapat masuk ke mesin worker tanpa diminta kata sandi setiap kali menggunakan command ***'ssh-copy-id'***

- **Master – worker1**

```
dina@master:~$ ssh-copy-id dina@worker1
/usr/bin/ssh-copy-id: INFO: Source of key(s) to be installed: "/home/dina/.ssh/id_rsa.pub"
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter out any that are al
ready installed

/usr/bin/ssh-copy-id: WARNING: All keys were skipped because they already exist on the remote syste
m.
                (if you think this is a mistake, you may want to use -f option)
```

- **Master – worker2**

```
dina@master:~$ ssh-copy-id dina@worker2
/usr/bin/ssh-copy-id: INFO: Source of key(s) to be installed: "/home/dina/.ssh/
id_rsa.pub"
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter
 out any that are already installed
/usr/bin/ssh-copy-id: INFO: 1 key(s) remain to be installed -- if you are promp
ted now it is to install the new keys
dina@worker2's password:

Number of key(s) added: 1

Now try logging into the machine, with:   "ssh 'dina@worker2'"
and check to make sure that only the key(s) you wanted were added.
```

- **Master – worker3**

```
dina@master:~$ ssh-copy-id dina@worker3
/usr/bin/ssh-copy-id: INFO: Source of key(s) to be installed: "/home/dina/.ssh/
id_rsa.pub"
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter
 out any that are already installed
/usr/bin/ssh-copy-id: INFO: 1 key(s) remain to be installed -- if you are promp
```

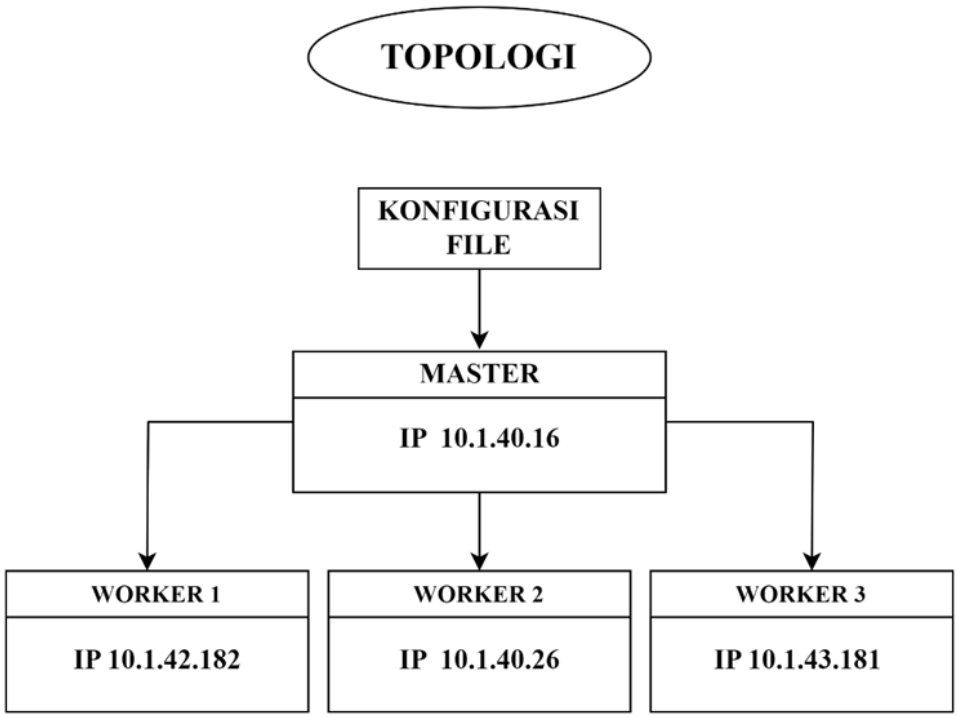
➢ **Testing**

Melakukan uji coba untuk menghasilkan perintah dasar python pada setiap device dengan hasil output **"Hello, World!"** dengan menggunakan command ***'mpirun -np <jumlah prosesor> -host <daftar host> python3 test.py'***

```
dina@master:~$ mpirun -n 4 -host master,worker1,worker2,worker3 python3 -m mpi4
py.bench helloworld
Hello, World! I am process 0 of 4 on master.
Hello, World! I am process 1 of 4 on worker1.
Hello, World! I am process 2 of 4 on worker2.
Hello, World! I am process 3 of 4 on worker3.
```

9. Numerik

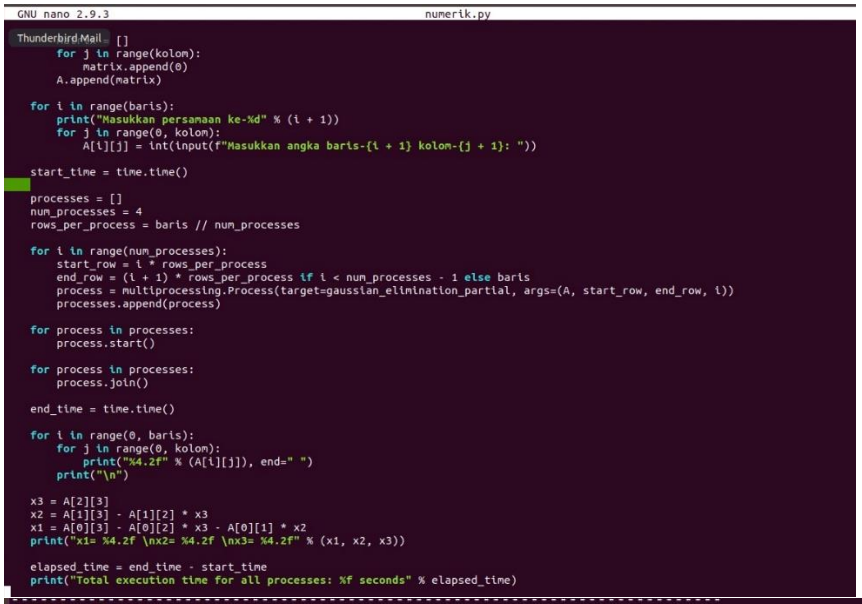
Numerik mengacu pada bidang matematika yang berkaitan dengan representasi, manipulasi, dan analisis angka (bilangan) serta metode perhitungan yang diterapkan pada masalah matematika atau ilmiah dalam bentuk numerik. Beberapa konsep umum dalam konteks numerik melibatkan representasi angka dalam bentuk biner, operasi aritmetika, analisis numerik, dan pemecahan masalah dengan menggunakan komputasi.



- **Eliminasi Gaussian**

  Eliminasi Gaussian, juga dikenal sebagai metode eliminasi Gauss atau eliminasi Gauss-Jordan, adalah suatu metode dalam aljabar linier yang digunakan untuk menyelesaikan sistem persamaan linear dan untuk menemukan invers matriks. Tujuan utama dari metode ini adalah untuk mentransformasikan matriks koefisien dari sistem persamaan linear menjadi bentuk matriks segitiga atas atau bentuk matriks segitiga bawah untuk kemudian melakukan substitusi mundur atau substitusi maju guna mendapatkan solusi sistem persamaan tersebut.

```
 GNU nano 2.9.3                          numerik.py

import time
import multiprocessing

def gaussian_elimination_partial(A, start_row, end_row, process_id):
    start_time = time.time()
    for i in range(start_row, end_row):
        diag = A[i][i]
        for j in range(kolom):
            A[i][j] /= diag
        for k in range(i + 1, kolom):
            if k != baris:
                diag1 = A[k][i]
                for j in range(kolom):
                    A[k][j] = A[k][j] - diag1 * A[i][j]
    end_time = time.time()
    print(f"Process {process_id} execution time: {end_time - start_time} seconds")

if __name__ == '__main__':
    ordo = int(input("Masukkan ordo matrix : "))
    baris = ordo
    kolom = ordo + 1

    A = []
    for i in range(baris):
        matrix = []
        for j in range(kolom):
            matrix.append(0)
        A.append(matrix)

    for i in range(baris):
        print("Masukkan persamaan ke-%d" % (i + 1))
        for j in range(0, kolom):
            A[i][j] = int(input(f"Masukkan angka baris-{i + 1} kolom-{j + 1}: "))

    start_time = time.time()

    processes = []
    num_processes = 4
    rows_per_process = baris // num_processes

    for i in range(num_processes):
        start_row = i * rows_per_process
        end_row = (i + 1) * rows_per_process if i < num_processes - 1 else baris
        process = multiprocessing.Process(target=gaussian_elimination_partial, args=(A, start_row, end_row, i))
        processes.append(process)

    for process in processes:
                                [ Read 66 lines ]
```



```
GNU nano 2.9.3                                numerik.py
Thunderbird Mail  []
        for j in range(kolom):
            matrix.append(0)
        A.append(matrix)

    for i in range(baris):
        print("Masukkan persamaan ke-%d" % (i + 1))
        for j in range(0, kolom):
            A[i][j] = int(input(f"Masukkan angka baris-{i + 1} kolom-{j + 1}: "))

    start_time = time.time()

    processes = []
    num_processes = 4
    rows_per_process = baris // num_processes

    for i in range(num_processes):
        start_row = i * rows_per_process
        end_row = (i + 1) * rows_per_process if i < num_processes - 1 else baris
        process = multiprocessing.Process(target=gausslan_elimination_partial, args=(A, start_row, end_row, i))
        processes.append(process)

    for process in processes:
        process.start()

    for process in processes:
        process.join()

    end_time = time.time()

    for i in range(0, baris):
        for j in range(0, kolom):
            print("%4.2f" % (A[i][j]), end=" ")
        print("\n")

    x3 = A[2][3]
    x2 = A[1][3] - A[1][2] * x3
    x1 = A[0][3] - A[0][2] * x3 - A[0][1] * x2
    print("x1= %4.2f \nx2= %4.2f \nx3= %4.2f" % (x1, x2, x3))

    elapsed_time = end_time - start_time
    print("Total execution time for all processes: %f seconds" % elapsed_time)
```

```
dina@master:~$ sudo nano numerik.py
dina@master:~$ mpirun -n 1 -host master,worker1,worker2,worker3 python3 numerik.py
Masukkan ordo matrix : 3
Masukkan persamaan ke-1
Masukkan angka baris-1 kolom-1: 1
Masukkan angka baris-1 kolom-2: 2
Masukkan angka baris-1 kolom-3: 3
Masukkan angka baris-1 kolom-4: 4
Masukkan persamaan ke-2
Masukkan angka baris-2 kolom-1: 4
Masukkan angka baris-2 kolom-2: 3
Masukkan angka baris-2 kolom-3: 2
Masukkan angka baris-2 kolom-4: 1
Masukkan persamaan ke-3
Masukkan angka baris-3 kolom-1: 2
Masukkan angka baris-3 kolom-2: 4
Masukkan angka baris-3 kolom-3: 7
Masukkan angka baris-3 kolom-4: 9
Process 0 execution time: 6.67572021484375e-06 seconds
Process 1 execution time: 7.62939453125e-06 seconds
Process 2 execution time: 1.5020370483398438e-05 seconds
Process 3 execution time: 3.743171691894531e-05 seconds
1.00 2.00 3.00 4.00

4.00 3.00 2.00 1.00

2.00 4.00 7.00 9.00

x1= 11.00
x2= -17.00
x3= 9.00
Total execution time for all processes: 0.033666 seconds
dina@master:~$
```

- **Newton – Raphson**

  Metode Newton-Raphson, juga dikenal sebagai metode Newton, adalah metode iteratif untuk menemukan akar dari suatu fungsi matematis. Metode ini menggunakan pendekatan linear untuk mendekati akar fungsi dan memerlukan turunan pertama dari fungsi tersebut. Metode Newton-Raphson dapat digunakan untuk menemukan akar persamaan nonlinier dan memiliki konvergensi cepat jika titik awal yang dipilih cukup dekat dengan akar sejati.

```
File  Edit  View  Search  Terminal  Help
  GNU nano 2.9.3                                  numerik2.py

import multiprocessing
import time

def f1(x):
    return x ** 2 - 20

def det_f1(x):
    return 2 * x

def newton_raphson(func, d_func, x, tolerence, max_iterations, real_root=None, process_id=0):
    if d_func(x) == 0:
        print("Newton-Raphson gagal dijalankan pada proses {0}.".format(process_id))
        return None
    else:
        iterations = 1
        start_time = time.time()
        while abs(func(x) / d_func(x)) >= tolerence and iterations <= max_iterations:
            current_iteration_print = "Proses {0}, Iterasi : {1}".format(process_id, iterations)
            if func(x) == 0:
                print(current_iteration_print + ", Solusi ditemukan : {0}".format(x))
                return x

            x = x - func(x) / d_func(x)
            if d_func(x) == 0:
                print("Newton-Raphson gagal dijalankan pada proses {0}.".format(process_id))
                return None
            current_iteration_print += ", {0}".format(x)
            iterations += 1

            end_time = time.time()
            elapsed_time = end_time - start_time
            current_iteration_print += ", Waktu per Iterasi: {0} detik".format(elapsed_time)

            print(current_iteration_print)

        print("\nProses {0}, Jumlah iterasi : ".format(process_id), iterations)
        print("Proses {0}, Hasil akhir : ".format(process_id), x)

if __name__ == '__main__':
    processes = []
    inputs = [(f1, det_f1, 1.5, 0.00001, 30, 1, i) for i in range(4)]  # 4 proses

    for input_data in inputs:
        p = multiprocessing.Process(target=newton_raphson, args=input_data)
        processes.append(p)
        p.start()
```

Ubuntu Software

```
dina@master:~$ mpirun -n 1 -host master,worker1,worker2,worker3 python3 numerik2.py
Proses 1, Iterasi : 1, 7.416666666666667, Waktu per Iterasi: 6.29425048828125e-05 detik
Proses 0, Iterasi : 1, 7.416666666666667, Waktu per Iterasi: 4.57763671875e-05 detik
Proses 3, Iterasi : 1, 7.416666666666667, Waktu per Iterasi: 4.9591064453125e-05 detik
Proses 1, Iterasi : 2, 5.056647940074907, Waktu per Iterasi: 0.003101825714111328 detik
Proses 2, Iterasi : 1, 7.416666666666667, Waktu per Iterasi: 4.9591064453125e-05 detik
Proses 1, Iterasi : 3, 4.505918637197902, Waktu per Iterasi: 0.003255128860473633 detik
Proses 2, Iterasi : 2, 5.056647940074907, Waktu per Iterasi: 0.002245187759399414 detik
Proses 1, Iterasi : 4, 4.472262596169605, Waktu per Iterasi: 0.0034024715423583984 detik
Proses 2, Iterasi : 3, 4.505918637197902, Waktu per Iterasi: 0.002353668212890625 detik
Proses 2, Iterasi : 4, 4.472262596169605, Waktu per Iterasi: 0.0023949146270751953 detik
Proses 1, Iterasi : 5, 4.47213595679263, Waktu per Iterasi: 0.003534555435180664 detik
Proses 2, Iterasi : 5, 4.47213595679263, Waktu per Iterasi: 0.00249481201171875 detik

Proses 1, Jumlah iterasi :  6

Proses 2, Jumlah iterasi : Proses 1, Hasil akhir :  4.47213595679263
 6
Proses 2, Hasil akhir :  4.47213595679263
Proses 0, Iterasi : 2, 5.056647940074907, Waktu per Iterasi: 0.0020194053649902344 detik
Proses 0, Iterasi : 3, 4.505918637197902, Waktu per Iterasi: 0.002707242965698242 detik
Proses 0, Iterasi : 4, 4.472262596169605, Waktu per Iterasi: 0.0027680397033691406 detik
Proses 0, Iterasi : 5, 4.47213595679263, Waktu per Iterasi: 0.002811908721923828 detik

Proses 0, Jumlah iterasi :  6
Proses 0, Hasil akhir :  4.47213595679263
Proses 3, Iterasi : 2, 5.056647940074907, Waktu per Iterasi: 0.002415895462036133 detik
Proses 3, Iterasi : 3, 4.505918637197902, Waktu per Iterasi: 0.0024902820587158203 detik
Proses 3, Iterasi : 4, 4.472262596169605, Waktu per Iterasi: 0.0025358200073242188 detik
Proses 3, Iterasi : 5, 4.47213595679263, Waktu per Iterasi: 0.0025768280029296875 detik

Proses 3, Jumlah iterasi :  6
Proses 3, Hasil akhir :  4.47213595679263
dina@master:~$
```