Introduction to Parallel Processing

Lecture 6 : MPI for Python

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MPI API

- Technically, exists only for C, C++, and Fortran
- Python interfaces to the the MPI API
  - Not an implementation of the interface, calls an existing implementation under the hood
  - Does not include every part of the MPI API

Installing MPI4PY

- First, you need to install an implementation of MPI (e.g. MPICH, OpenMPI, MVAPICH, etc)

- Then, you can install MPI4PY to wrap that installed implementation

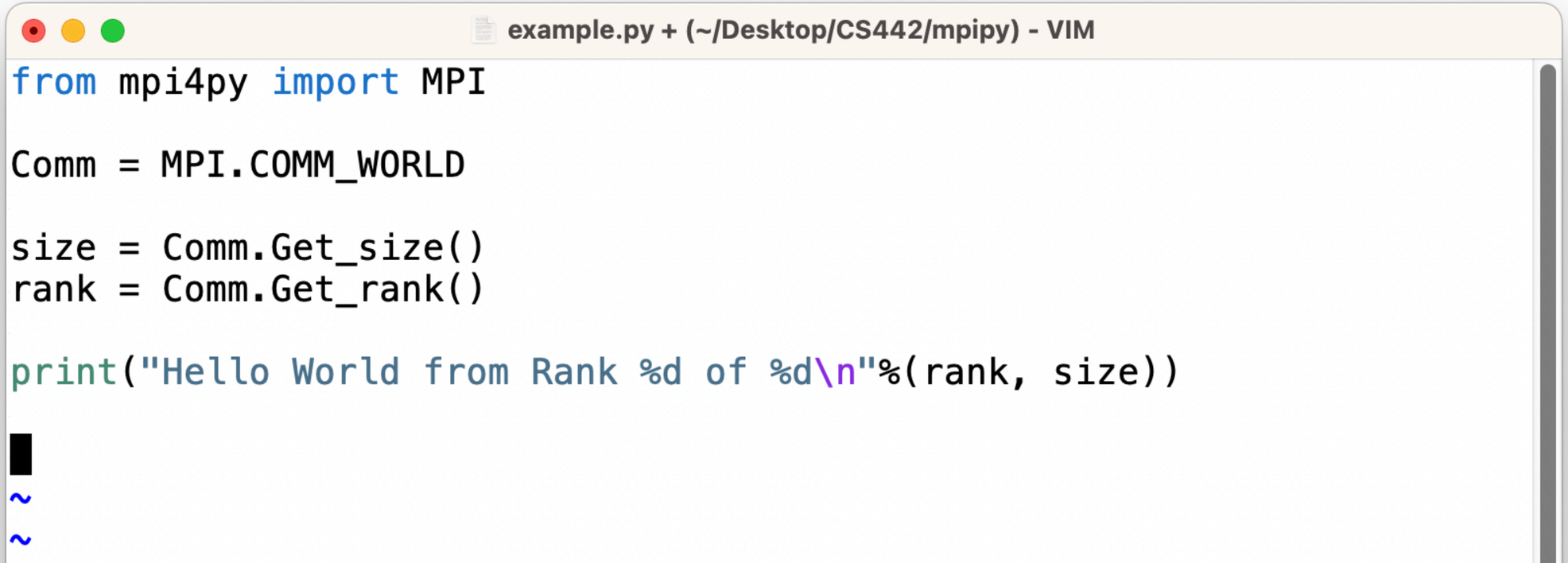
  - pip install mpi4py

  - https://mpi4py.readthedocs.io/en/stable/install.html

  - **CARC : module load miniconda3**
    conda create -n mpi_numpy mpi mpi4py numpy
    https://www.youtube.com/watch?v=JrCMi3_yCA0

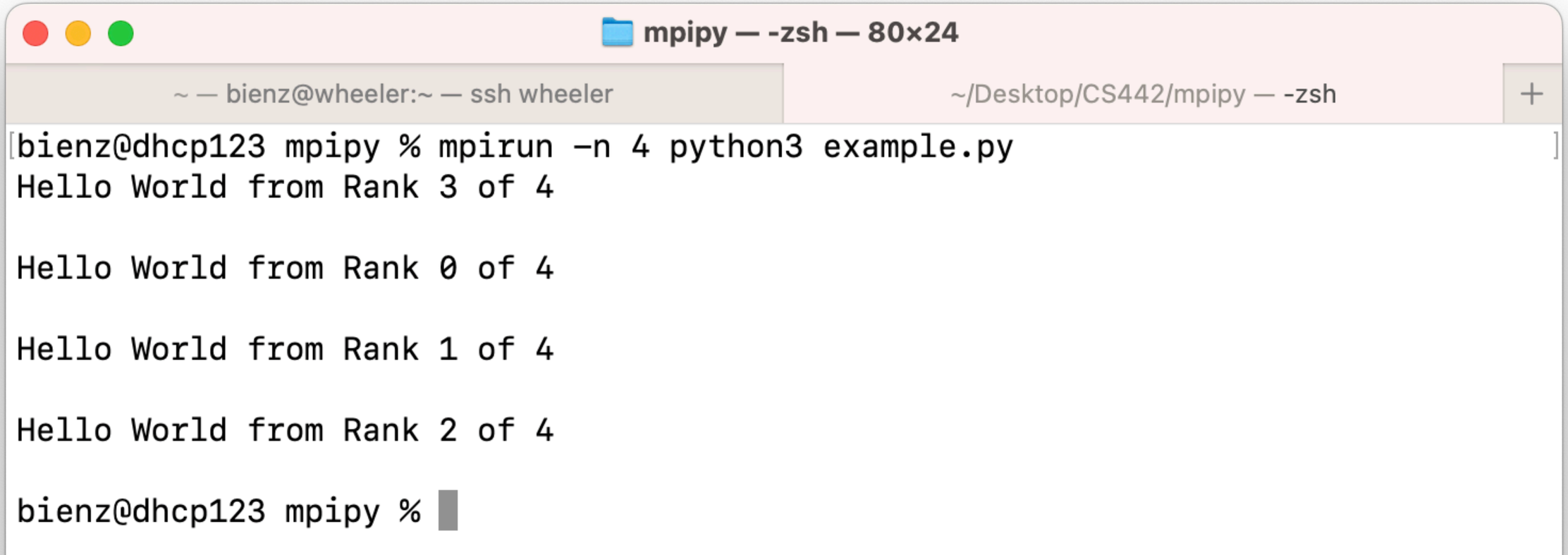
Hello World

- No MPI_Init/MPI_Finalize needed in Python
- Simply import MPI from mpi4py



Running Hello World

- No compilation as python is scripted language
- Still need to launch with mpirun

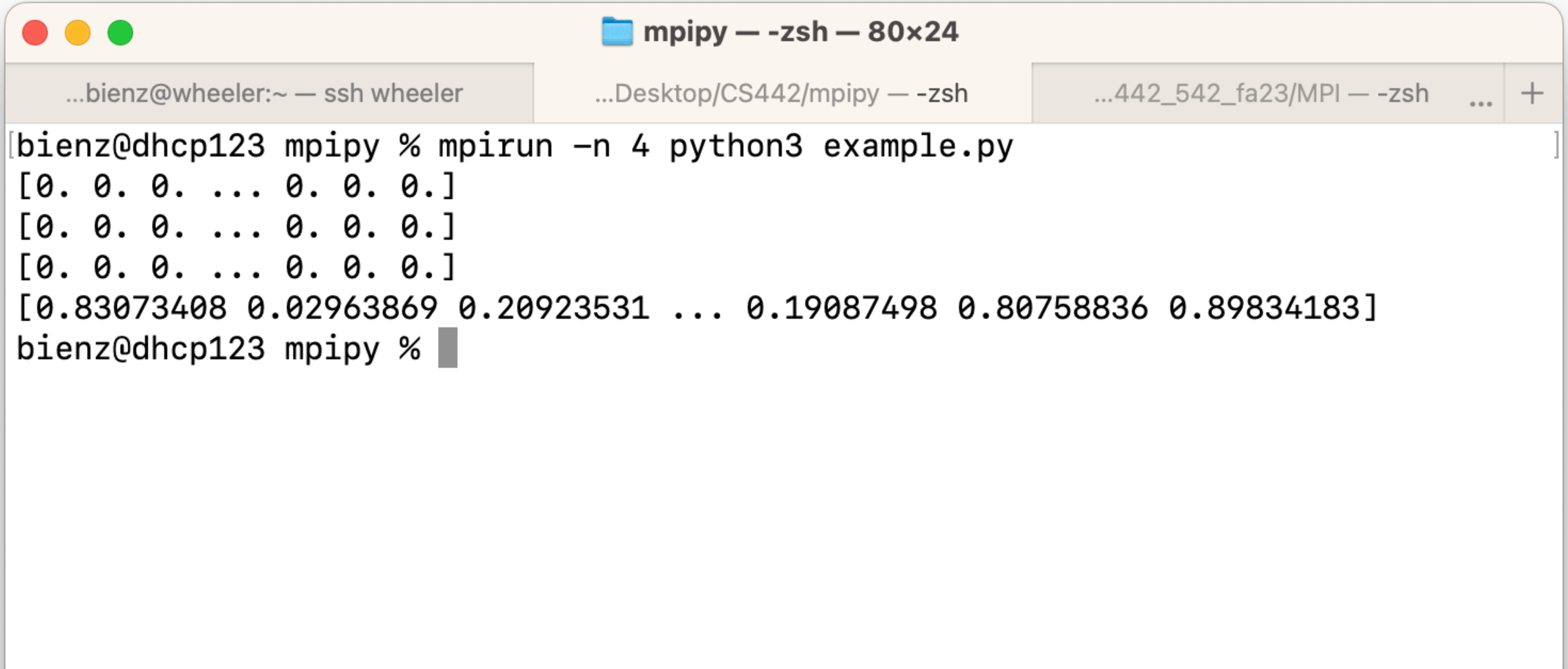


Point to Point Communication

example.py (~/Desktop/CS442/mpipy) - VIM

```
from mpi4py import MPI
import numpy as np

Comm = MPI.COMM_WORLD

size = Comm.Get_size()
rank = Comm.Get_rank()

proc = rank - 1
if (rank % 2 == 0):
    proc = rank + 1

size = 10000
array = np.random.rand(size);
array_recv = np.zeros(size);

if (rank == 0):
    Comm.Send(array, 1, tag=1234)
elif (rank == 1):
    Comm.Recv(array_recv, 0, tag=1234)

print(array_recv)
```

Point to Point Communication



Point to Point Communication

- Want every process to exchange with neighboring (e.g. rank 0 exchanges with rank 1, rank 2 with rank 3, etc)

example.py (~/Desktop/CS442/mpipy) - VIM

```
from mpi4py import MPI
import numpy as np

Comm = MPI.COMM_WORLD

size = Comm.Get_size()
rank = Comm.Get_rank()

proc = rank - 1
if (rank % 2 == 0):
    proc = rank + 1

size = 10000
array = np.random.rand(size);
array_recv = np.zeros(size);

Comm.Send(array, proc, tag=1234)
Comm.Recv(array_recv, proc, tag=1234)

print(array_recv)
```

Will this work??

Point to Point Communication

- Python is wrapping standard MPI implementation, meaning if there is an issue in MPI it will also be an issue in MPI4PY
- **All processes are sending at same time, so all may hang waiting for matching receive!**

Point to Point Communication

example.py (~/Desktop/CS442/mpipy) - VIM

```
from mpi4py import MPI
import numpy as np

Comm = MPI.COMM_WORLD

size = Comm.Get_size()
rank = Comm.Get_rank()

proc = rank - 1
if (rank % 2 == 0):
    proc = rank + 1

size = 10000
array = np.random.rand(size);
array_recv = np.zeros(size);

if (rank % 2):
    Comm.Send(array, proc, tag=1234)
    Comm.Recv(array_recv, proc, tag=1234)
else:
    Comm.Recv(array_recv, proc, tag=1234)
    Comm.Send(array, proc, tag=1234)

print(array_recv)

~
```

MPI Sendrecv Still Exists

example.py (~/Desktop/CS442/mpipy) - VIM

```
from mpi4py import MPI
import numpy as np

Comm = MPI.COMM_WORLD

size = Comm.Get_size()
rank = Comm.Get_rank()

proc = rank - 1
if (rank % 2 == 0):
    proc = rank + 1

size = 10000
array = np.random.rand(size);
array_recv = np.zeros(size);

Comm.Sendrecv(array, proc, sendtag=1234, recvbuf=array_recv, source=proc, recvtag=1234)

print(array_recv)

~
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~
~
```

As Does Non-Blocking Communication

example.py (~/Desktop/CS442/mpipy) - VIM

```
from mpi4py import MPI
import numpy as np

Comm = MPI.COMM_WORLD

size = Comm.Get_size()
rank = Comm.Get_rank()

proc = rank - 1
if (rank % 2 == 0):
    proc = rank + 1

size = 10000
array = np.random.rand(size);
array_recv = np.zeros(size);

send_req = Comm.Isend(array, proc, tag=1234)
recv_req = Comm.Irecv(array_recv, proc, tag=1234)
send_req.Wait()
recv_req.Wait()

print(array_recv)
~
~
~
```

Can Send to Everyone

example.py + (~/Desktop/CS442/mpipy) - VIM

```
from mpi4py import MPI
import numpy as np

Comm = MPI.COMM_WORLD

num_procs = Comm.Get_size()
rank = Comm.Get_rank()

size = 10000
array = np.random.rand(size);
array_recv = np.zeros(size);
n = size / num_procs

send_req = list()
recv_req = list()

for proc in range(num_procs):
    start = (int)(proc*n)
    end = (int)((proc+1)*n)
    send_req.append(Comm.Isend(array[start:end], proc, tag=1234))
    recv_req.append(Comm.Irecv(array_recv[start:end], proc, tag=1234))
MPI.Request.Waitall(send_req)
MPI.Request.Waitall(recv_req)

print(array_recv)

~
```

Can Specify Data Type

example.py (~/Desktop/CS442/mpipy) - VIM

```
from mpi4py import MPI
import numpy as np

Comm = MPI.COMM_WORLD

size = Comm.Get_size()
rank = Comm.Get_rank()

proc = rank - 1
if (rank % 2 == 0):
    proc = rank + 1

size = 10000
array = np.random.rand(size);
array_recv = np.zeros(size);

if (rank % 2):
    Comm.Send([array, MPI.DOUBLE], proc, tag=1234)
    Comm.Recv([array_recv, MPI.DOUBLE], proc, tag=1234)
else:
    Comm.Recv([array_recv, MPI.DOUBLE], proc, tag=1234)
    Comm.Send([array, MPI.DOUBLE], proc, tag=1234)

print(array_recv)

~
~
```

MPI Collectives : Bcast

example.py (~/Desktop/CS442/mpipy) - VIM

```
from mpi4py import MPI
import numpy as np

Comm = MPI.COMM_WORLD

size = Comm.Get_size()
rank = Comm.Get_rank()

root = 0
size = 10000
array = ""
if rank == root:
    array = np.random.rand(size);

array = Comm.bcast(array, root)

print(array)

~
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~
```

mpipy — -zsh — 80×24

...bienz@wheeler:~ — ssh wheeler | ...Desktop/CS442/mpipy — -zsh | ...442_542_fa23/MPI — -zsh

```
bienz@dhcp123 mpipy % mpirun -n 4 python3 example.py
[0.80592772 0.11930063 0.38635772 ... 0.56694023 0.81398224 0.1095385 ]
[0.80592772 0.11930063 0.38635772 ... 0.56694023 0.81398224 0.1095385 ]
[0.80592772 0.11930063 0.38635772 ... 0.56694023 0.81398224 0.1095385 ]
[0.80592772 0.11930063 0.38635772 ... 0.56694023 0.81398224 0.1095385 ]
bienz@dhcp123 mpipy %
```

MPI Collectives : Scatter

example.py (~/Desktop/CS442/mpipy) - VIM

```python
from mpi4py import MPI
import numpy as np

Comm = MPI.COMM_WORLD

num_procs = Comm.Get_size()
rank = Comm.Get_rank()

root = 0
size = 10000
n = (int)(size / num_procs)
array = list()
if rank == root:
    for i in range(num_procs):
        array.append(np.random.rand(n))
    print(array)

array = Comm.scatter(array, root)

print(array)
```

mpipy — -zsh ▸ Python — 80×24

...bienz@wheeler:~ — ssh wheeler | ...S442/mpipy — -zsh ▸ Python | ...442_542_fa23/MPI — -zsh

```
bienz@dhcp123 mpipy % mpirun -n 4 python3 example.py
[0.51850718 0.32444375 0.98629275 ... 0.54781665 0.46742699 0.20022401]
[0.22813997 0.55830664 0.56853193 ... 0.04786992 0.05984303 0.21836289]
[array([0.11046019, 0.70137999, 0.83631137, ..., 0.44476161, 0.31741309,
        0.34553758]), array([0.51850718, 0.32444375, 0.98629275, ..., 0.54781
 0.46742699,
        0.20022401]), array([0.22813997, 0.55830664, 0.56853193, ..., 0.04786
 0.05984303,
        0.21836289]), array([0.36581572, 0.11326732, 0.16167195, ..., 0.41059
 0.47575342,
        0.68221024])]
[0.11046019 0.70137999 0.83631137 ... 0.44476161 0.31741309 0.34553758]
[0.36581572 0.11326732 0.16167195 ... 0.41059474 0.47575342 0.68221024]
bienz@dhcp123 mpipy %
```

MPI Collectives : Gather

example.py (~/Desktop/CS442/mpipy) - VIM

```
from mpi4py import MPI
import numpy as np

Comm = MPI.COMM_WORLD

num_procs = Comm.Get_size()
rank = Comm.Get_rank()

root = 0
size = 10000
n = (int)(size / num_procs)
array = np.random.rand(n)
print(array)

array = Comm.gather(array, root)

if rank == root:
    print(array)
~
```

mpipy — -zsh ▸ Python — 80×24

...bienz@wheeler:~ — ssh wheeler | ...S442/mpipy — -zsh ▸ Python | ...442_542_fa23/MPI — -zsh

```
bienz@dhcp123 mpipy % mpirun -n 4 python3 example.py
[0.63137449 0.14613175 0.31386525 ... 0.40202934 0.03975134 0.33843775]
[0.77241016 0.94620565 0.68912371 ... 0.08507317 0.781987   0.75293553]
[0.33287514 0.7383226  0.8269368  ... 0.72451843 0.05116583 0.14933154]
[0.37301632 0.50065708 0.95537867 ... 0.21186825 0.62165606 0.20253242]
[array([0.37301632, 0.50065708, 0.95537867, ..., 0.21186825, 0.62165606,
        0.20253242]), array([0.77241016, 0.94620565, 0.68912371, ..., 0.08507317
 0.781987  ,
        0.75293553]), array([0.63137449, 0.14613175, 0.31386525, ..., 0.40202934
 0.03975134,
        0.33843775]), array([0.33287514, 0.7383226 , 0.8269368 , ..., 0.72451843
 0.05116583,
        0.14933154])]
bienz@dhcp123 mpipy %
```

Different Datatypes, Different Sizes

example.py (~/Desktop/CS442/mpipy) - VIM

```
from mpi4py import MPI
import numpy as np

Comm = MPI.COMM_WORLD

num_procs = Comm.Get_size()
rank = Comm.Get_rank()

root = 0
array = ""
if rank == root:
    array = ["hello", 45, [1234], "goodbye"]

array = Comm.scatter(array, root)

print(array)
~
~
~
```

mpipy — -zsh ▸ Pyth

...bienz@wheeler:~ — ssh wheeler | ...S442/mpipy — -zsh

```
bienz@dhcp123 mpipy % mpirun -n 4 python3 e
hello
[1234]
45
goodbye
bienz@dhcp123 mpipy %
```