transfer_quad_dot

May 15, 2022

[ ]:
```
## according to cpuworld opteron 6272 is bulldozer cpu with '16' cores. That means only 8 fpu's and 16 alus represented as 16 cores.
## And the task use fpu. L2 cache is 'shared' per 2 ALU 1 FPU (1 block). L3 is shared. According to cpuworld 2x8mB L3 points to NUMA
## 4 + 4 blocks. The task uses memory much more than calculation (~128M for 64bit double). So optimal perf is predicted at 4 threads.
## And yes there is definite dip there.

import numpy as np
import subprocess
from mpl_toolkits import mplot3d
import ipympl
%matplotlib ipympl
import matplotlib.pyplot as plt
plt.style.use('dark_background')
from tabulate import tabulate
from tqdm import tqdm
```

[ ]:
```
x_max = 5
t_max = 10
# 3d surface work properly only when x_points == t_points
x_points = 512
t_points = 512
n_proc = 6

plt_rcount = 128
plt_ccount = 128

t_points_at_x_var = 100
x_points_start = n_proc
x_points_end = 25000
x_var_step = 1000

x_points_at_t_var = 100
t_points_start = 10
t_points_end = 25000
t_var_step = 1000
```

```
np_start = 1
np_end = 6
t_points_at_np_var = 4096
x_points_at_np_var = 4096
```

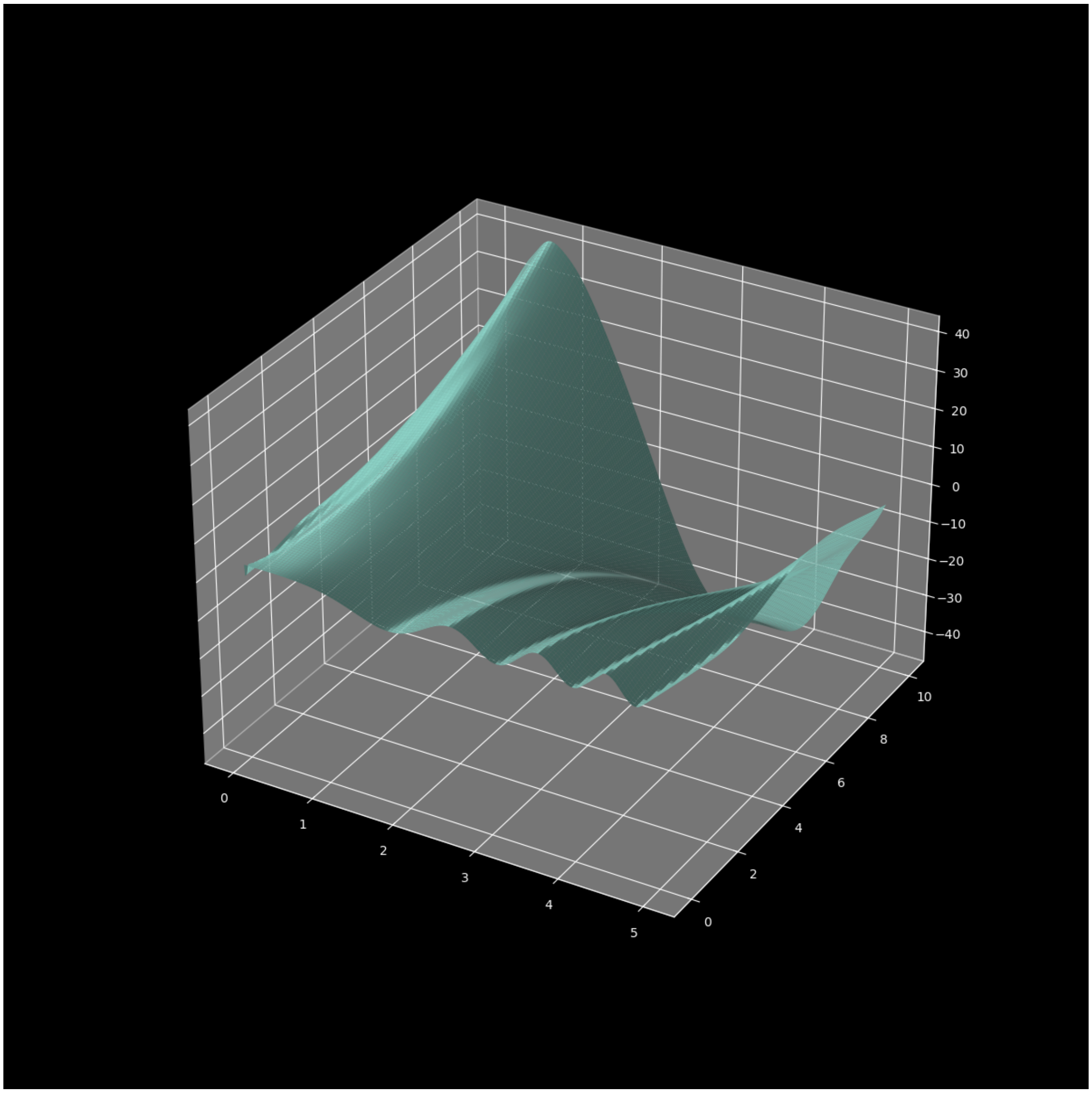
[ ]:

```
matrix = np.zeros ((x_points, x_points))
perf_ranks = np.zeros ((n_proc, 3))
result = subprocess.run (["mpirun", "-np", "{0}".format (n_proc), "./transfer",␣
 ↪"{0}".format (x_points), "{0}".format (t_points), "{0}".format (x_max),␣
 ↪"{0}".format (t_max), "{0}".format (t_points - x_points), "{0}".format␣
 ↪(t_points)], capture_output=True, text=True)
res_split = result.stdout.split ()
for i in range (0, x_points):
    for j in range (0, x_points):
        matrix[i][j] = res_split[i * x_points + j]
for i in range (0, n_proc):
    rank = res_split[x_points * x_points + i * 4]
    for j in range (0, 3):
        perf_ranks[int (rank)][j] = res_split[x_points * x_points + i * 4 + j +␣
 ↪1]
#print ("last layer :")
#print (matrix[x_points - 1])

tabledata = []
for i in range (0, n_proc):
    temp = []
    temp.append (i)
    temp.append (perf_ranks[i][0])
    temp.append (perf_ranks[i][1])
    temp.append (perf_ranks[i][2])
    tabledata.append (temp)
print (tabulate (tabledata, headers = ["rank", "calc time", "gather time",␣
 ↪"total time"]))

X = np.outer (np.linspace (0, x_max, x_points), np.ones (x_points)).copy().T
T = np.outer (np.linspace (0, t_max, x_points), np.ones (x_points))
plt.figure(figsize=(12, 12))
plt.axes(projection ='3d').plot_surface (X, T, matrix, rcount = plt_rcount,␣
 ↪ccount = plt_ccount)
```

```
  rank    calc time    gather time    total time
------  -----------  -------------  ------------
     0   0.00297432    0.00204494     0.10245
     1   0.00299263    0.000884889    0.00388267
     2   0.00305569    0.00111131     0.00439418
     3   0.00302641    0.00132657     0.00435867
```

```
4   0.00302462    0.00156317     0.00488476
5   0.00302268    0.00185073     0.00488193
```

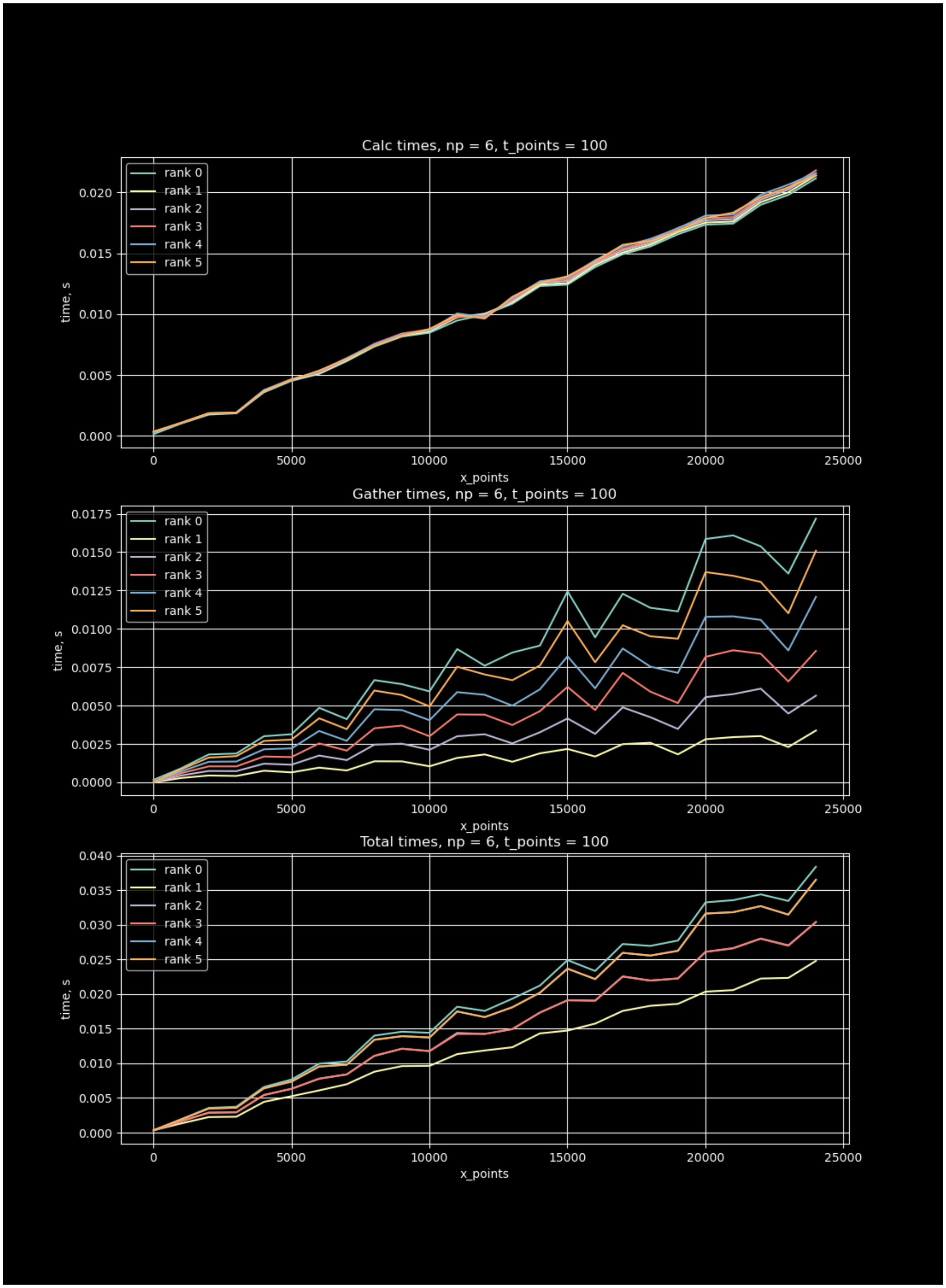
```
[ ]: <mpl_toolkits.mplot3d.art3d.Poly3DCollection at 0x7f13cc767fd0>
```



```
[ ]: ### x_points var at host
x_points_var = np.zeros (int ((x_points_end - x_points_start) / x_var_step) + 1)
times = np.zeros ((3, n_proc, int ((x_points_end - x_points_start) /␣
  ↪x_var_step) + 1))
i = x_points_start
k = 0
tabledata = []
with tqdm(total=int ((x_points_end - x_points_start) / x_var_step) + 1) as pbar:
    while i < x_points_end:
        result = subprocess.run (["mpirun", "-np", "{0}".format (n_proc), "./transfer", "{0}".format (i), "{0}".format (t_points_at_x_var), "{0}".format (x_max), "{0}".format (t_max), "n"], capture_output=True, text=True)
        res_split = result.stdout.split ()
        times_max = np.zeros (3)
        for p in range (0, n_proc):
            rank = int (res_split[p * 4])
            for j in range (0, 3):
                times[j][rank][k] = res_split[p * 4 + j + 1]
                if times[j][rank][k] > times_max[j]:
                    times_max[j] = times[j][rank][k]
        x_points_var[k] = i
        temp = []
        temp.append (i)
        temp.append (times_max[0])
        temp.append (times_max[1])
        temp.append (times_max[2])
        tabledata.append (temp)
        i = i + x_var_step
        k = k + 1
        pbar.update (1)

print (tabulate (tabledata, headers = ["x_points", "max calc time", "max gather time", "max total time"]))

plt.figure (figsize = [11, 15])

plt.subplot (311)
plt.grid ()
plt.title ("Calc times, np = {0}, t_points = {1}".format(n_proc, t_points_at_x_var))
plt.xlabel ("x_points")
plt.ylabel ("time, s")
for i in range(0, n_proc):
    plt.plot (x_points_var, times[0][i], 'C{0}'.format (i), label = 'rank {0}'.format(i))
plt.legend ()

plt.subplot (312)
plt.grid ()
plt.title ("Gather times, np = {0}, t_points = {1}".format(n_proc, t_points_at_x_var))
plt.xlabel ("x_points")
plt.ylabel ("time, s")
for i in range(0, n_proc):
    plt.plot (x_points_var, times[1][i], 'C{0}'.format (i), label = 'rank {0}'.
  ↪format(i))
plt.legend ()

plt.subplot (313)
plt.grid ()
plt.title ("Total times, np = {0}, t_points = {1}".format(n_proc,␣
  ↪t_points_at_x_var))
plt.xlabel ("x_points")
plt.ylabel ("time, s")
for i in range(0, n_proc):
    plt.plot (x_points_var, times[2][i], 'C{0}'.format (i), label = 'rank {0}'.
  ↪format(i))
plt.legend ()
```

```
100%|          | 25/25 [00:03<00:00,  8.03it/s]

  x_points    max calc time    max gather time    max total time
----------  ---------------  -----------------  ----------------
         6      0.000334664        0.000162522       0.000353655
      1006      0.00106565         0.000914293       0.00192486
      2006      0.00185866         0.00181799        0.00356219
      3006      0.00190991         0.00187793        0.00373066
      4006      0.00375612         0.00300506        0.00658599
      5006      0.00466908         0.00313637        0.00766414
      6006      0.00535995         0.00485659        0.00994894
      7006      0.00638749         0.00411773        0.0102637
      8006      0.0075638          0.00666179        0.0139969
      9006      0.00840371         0.00640035        0.014566
     10006      0.00877964         0.00592765        0.014408
     11006      0.0100564          0.00868677        0.01817
     12006      0.0100315          0.00760169        0.0175674
     13006      0.0114232          0.0084607         0.0193251
     14006      0.0126983          0.0089113         0.0212248
     15006      0.0131137          0.012446          0.0248909
     16006      0.0144344          0.00945071        0.0233277
     17006      0.0156947          0.0122884         0.0272199
     18006      0.0161833          0.0113763         0.0269432
     19006      0.0170861          0.0111418         0.0277179
     20006      0.0180978          0.0158593         0.0332235
     21006      0.018341           0.0160921         0.0335437
     22006      0.0198127          0.01538           0.0343784
     23006      0.0206405          0.0136054         0.0334342
     24006      0.0218207          0.0171934         0.0383689
```

```
[ ]: <matplotlib.legend.Legend at 0x7f13c5901ea0>
```

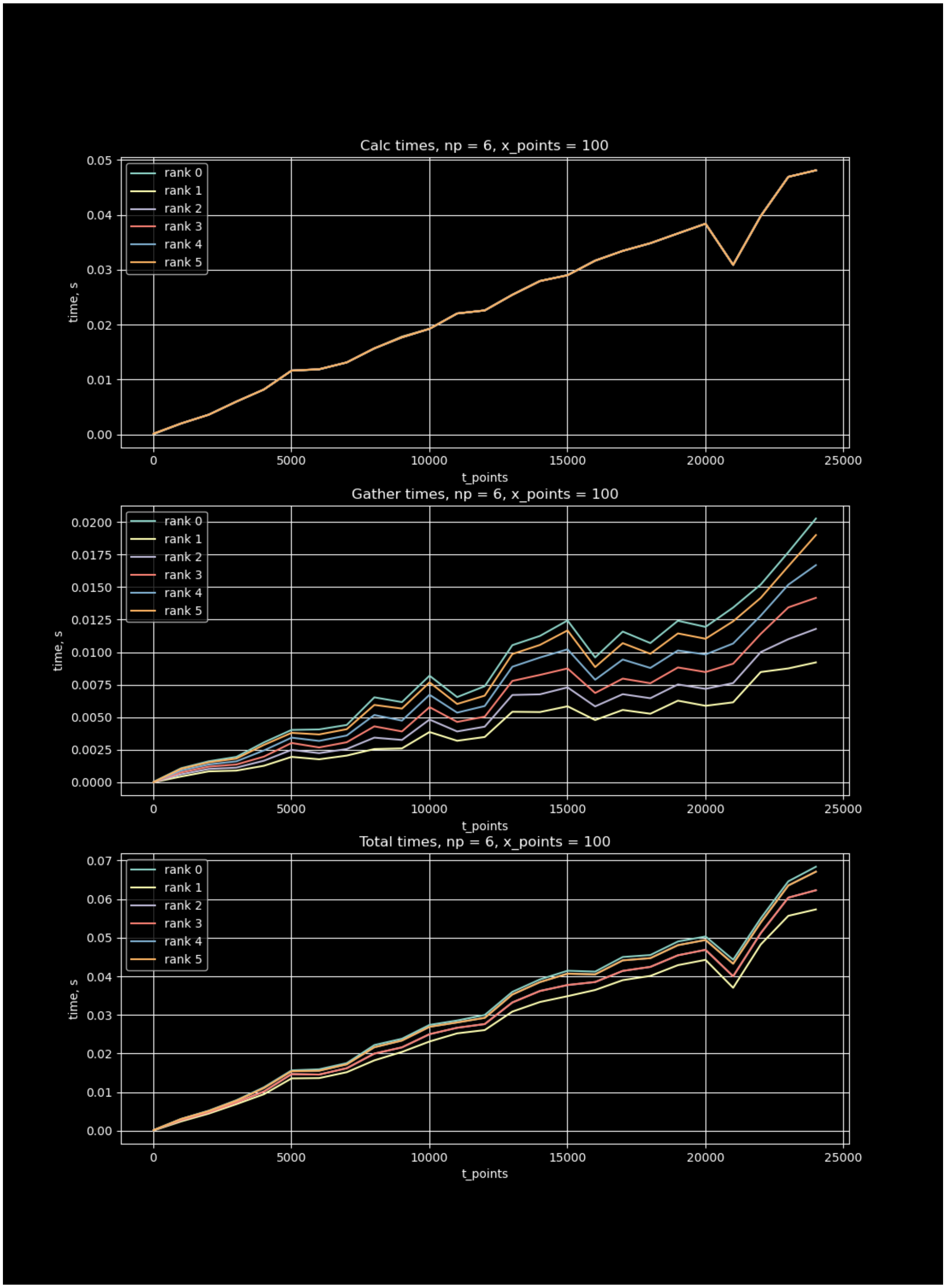

Calc times, np = 6, t_points = 100
time, s
x_points
0.000
0.005
0.010
0.015
0.020
0
5000
10000
15000
20000
25000
rank 0
rank 1
rank 2
rank 3
rank 4
rank 5
Gather times, np = 6, t_points = 100
time, s
x_points
0.0000
0.0025
0.0050
0.0075
0.0100
0.0125
0.0150
0.0175
0
5000
10000
15000
20000
25000
rank 0
rank 1
rank 2
rank 3
rank 4
rank 5
Total times, np = 6, t_points = 100
time, s
x_points
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
0
5000
10000
15000
20000
25000
rank 0
rank 1
rank 2
rank 3
rank 4
rank 5

```
[ ]: ### t_points var at host
t_points_var = np.zeros (int ((t_points_end - t_points_start) / t_var_step) + 1)
times = np.zeros ((3, n_proc, int ((t_points_end - t_points_start) /␣
 ↪t_var_step) + 1))
i = t_points_start
k = 0
tabledata = []
with tqdm (total = int ((t_points_end - t_points_start) / t_var_step) + 1) as␣
 ↪pbar:
    while i < t_points_end:
        result = subprocess.run (["mpirun", "-np", "{0}".format (n_proc), "./
 ↪transfer", "{0}".format (x_points_at_t_var), "{0}".format (i), "{0}".format␣
 ↪(x_max), "{0}".format (t_max), "n"], capture_output=True, text=True)
        res_split = result.stdout.split ()
        times_max = np.zeros (3)
        for p in range (0, n_proc):
            rank = int (res_split[p * 4])
            for j in range (0, 3):
                times[j][rank][k] = res_split[p * 4 + j + 1]
                if times[j][rank][k] > times_max[j]:
                    times_max[j] = times[j][rank][k]
        t_points_var[k] = i
        temp = []
        temp.append (i)
        temp.append (times_max[0])
        temp.append (times_max[1])
        temp.append (times_max[2])
        tabledata.append (temp)
        i = i + t_var_step
        k = k + 1
        pbar.update (1)

print (tabulate (tabledata, headers = ["t_points", "max calc time", "max gather␣
 ↪time", "max total time"]))

plt.figure (figsize = [11, 15])

plt.subplot (311)
plt.grid ()
plt.title ("Calc times, np = {0}, x_points = {1}".format(n_proc,␣
 ↪x_points_at_t_var))
plt.xlabel ("t_points")
plt.ylabel ("time, s")
for i in range(0, n_proc):
    plt.plot (t_points_var, times[0][i], 'C{0}'.format (i), label = 'rank {0}'.
 ↪format(i))
plt.legend ()
plt.subplot (312)
plt.grid ()
plt.title ("Gather times, np = {0}, x_points = {1}".format(n_proc,␣
 ↪x_points_at_t_var))
plt.xlabel ("t_points")
plt.ylabel ("time, s")
for i in range(0, n_proc):
    plt.plot (t_points_var, times[1][i], 'C{0}'.format (i), label = 'rank {0}'.
 ↪format(i))
plt.legend ()

plt.subplot (313)
plt.grid ()
plt.title ("Total times, np = {0}, x_points = {1}".format(n_proc,␣
 ↪x_points_at_t_var))
plt.xlabel ("t_points")
plt.ylabel ("time, s")
for i in range(0, n_proc):
    plt.plot (t_points_var, times[2][i], 'C{0}'.format (i), label = 'rank {0}'.
 ↪format(i))
plt.legend ()
```

```
100%|      | 25/25 [00:03<00:00,  7.28it/s]

  t_points    max calc time    max gather time    max total time
----------  ---------------  -----------------  ----------------
        10      0.000144851        3.847e-05         0.000188801
      1010      0.00201668         0.00108562        0.00309018
      2010      0.00360928         0.00161894        0.00522673
      3010      0.00599362         0.00195379        0.00792532
      4010      0.00819884         0.00306983        0.011279
      5010      0.0116494          0.00402666        0.0156583
      6010      0.0118772          0.00406544        0.0159296
      7010      0.0131275          0.00440785        0.0175292
      8010      0.0156918          0.00652879        0.0222072
      9010      0.0178125          0.0061613         0.0238436
     10010      0.0192554          0.00819039        0.0274291
     11010      0.0220436          0.00654606        0.0285692
     12010      0.0225948          0.00738434        0.0299973
     13010      0.0254439          0.0105341         0.035989
     14010      0.0279511          0.0112435         0.0392048
     15010      0.0290364          0.0124305         0.0414547
     16010      0.0316732          0.00959201        0.0412271
     17010      0.0334425          0.0115773         0.0450127
     18010      0.0348426          0.010693          0.0455199
     19010      0.0366276          0.0124093         0.0490252
     20010      0.038393           0.0119387         0.0503268
```

```
    21010      0.0308933          0.0134223        0.0443101
    22010      0.0398232          0.0151909        0.0550238
    23010      0.0469319          0.0176738        0.0646131
    24010      0.0481136          0.0202599        0.0683889
```

```
[ ]: <matplotlib.legend.Legend at 0x7f13c4e935e0>
```



Calc times, np = 6, x_points = 100

Gather times, np = 6, x_points = 100

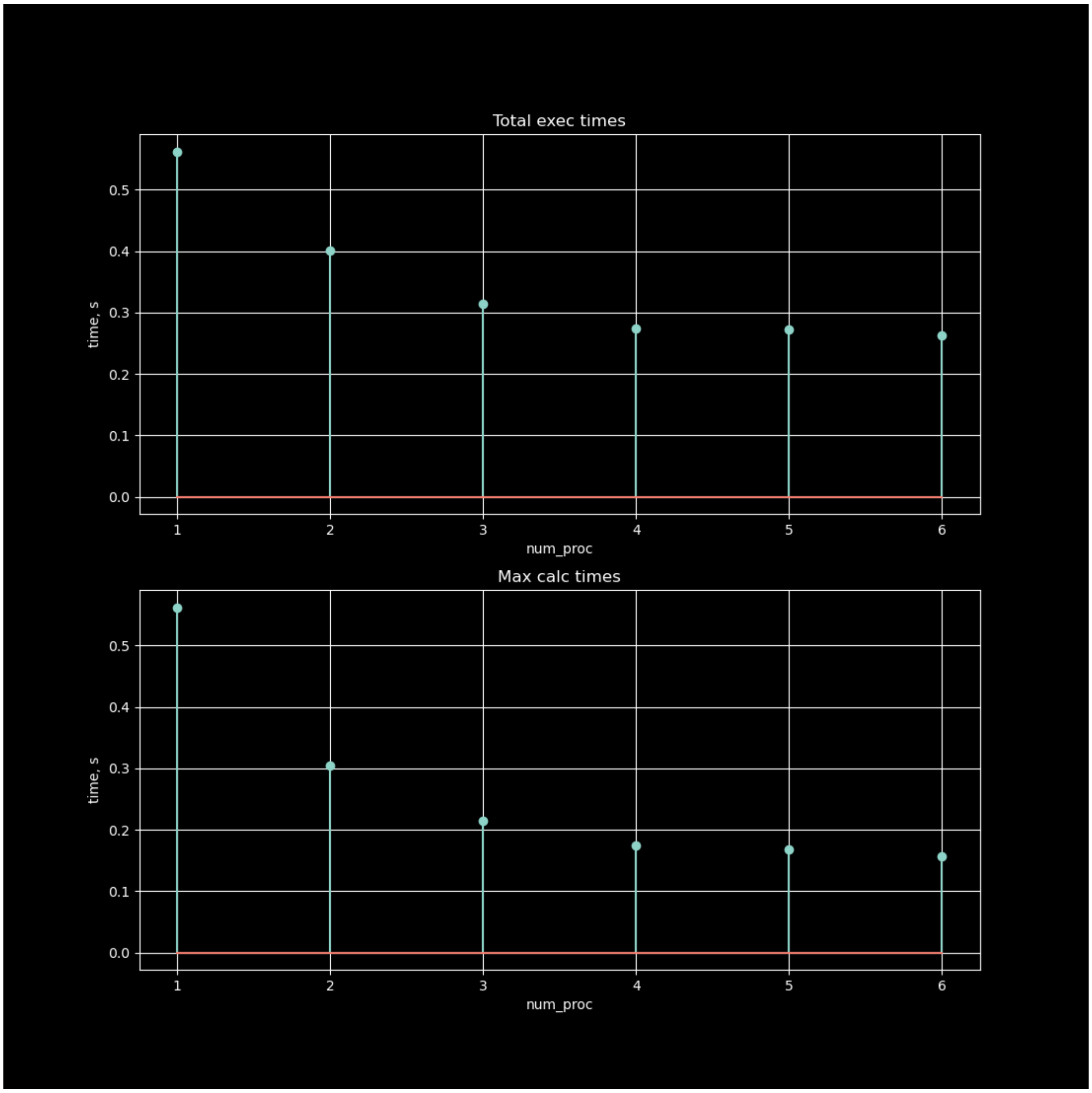
Total times, np = 6, x_points = 100

[ ]:

```
### np var at host

np_var = np.arange (np_start, np_end + 1)
times = np.zeros ((3, np_end - np_start + 1))
i = np_start
tabledata = []
with tqdm (total = np_end - np_start + 1) as pbar:
    while i <= np_end:
        result = subprocess.run (["mpirun", "-np", "{0}".format (i), "./
 ↪transfer", "{0}".format (x_points_at_np_var), "{0}".format␣
 ↪(t_points_at_np_var), "{0}".format (x_max), "{0}".format (t_max), "n"],␣
 ↪capture_output=True, text=True)
        res_split = result.stdout.split ()
        max_calc = 0
        max_gather = 0
        max_total = 0
        for p in range (0, i - np_start + 1):
            if float (res_split[p * 4 + 1]) > max_calc:
                max_calc = float (res_split[p * 4 + 1])
            if float (res_split[p * 4 + 2]) > max_gather:
                max_gather = float (res_split[p * 4 + 2])
            if float (res_split[p * 4 + 3]) > max_total:
                max_total = float (res_split[p * 4 + 3])

        times[0][i - np_start] = max_calc
        times[1][i - np_start] = max_gather
        times[2][i - np_start] = max_total
        temp = []
        temp.append (i)
        temp.append (max_calc)
        temp.append (max_gather)
        temp.append (max_total)
        tabledata.append (temp)
        i = i + 1
        pbar.update (1)

print (tabulate (tabledata, headers = ["N proc", "max calc time", "max gather␣
 ↪time", "max total time"]))

plt.figure (figsize = [11, 11])

plt.subplot (211)
plt.grid ()
plt.title ("Total exec times")
plt.xlabel ("num_proc")
plt.ylabel ("time, s")
plt.stem (np_var, times[2])
plt.subplot (212)
plt.grid ()
plt.title ("Max calc times")
plt.xlabel ("num_proc")
plt.ylabel ("time, s")
plt.stem (np_var, times[0])
```

```
100%|     | 6/6 [00:02<00:00,  2.06it/s]

  N proc    max calc time    max gather time    max total time
--------  ---------------  -----------------  ----------------
       1         0.562681        4.8e-08              0.562699
       2         0.305381        0.096367             0.401713
       3         0.213957        0.100156             0.314129
       4         0.174824        0.0988103            0.27346
       5         0.167608        0.104488             0.272036
       6         0.157372        0.105235             0.26248
```

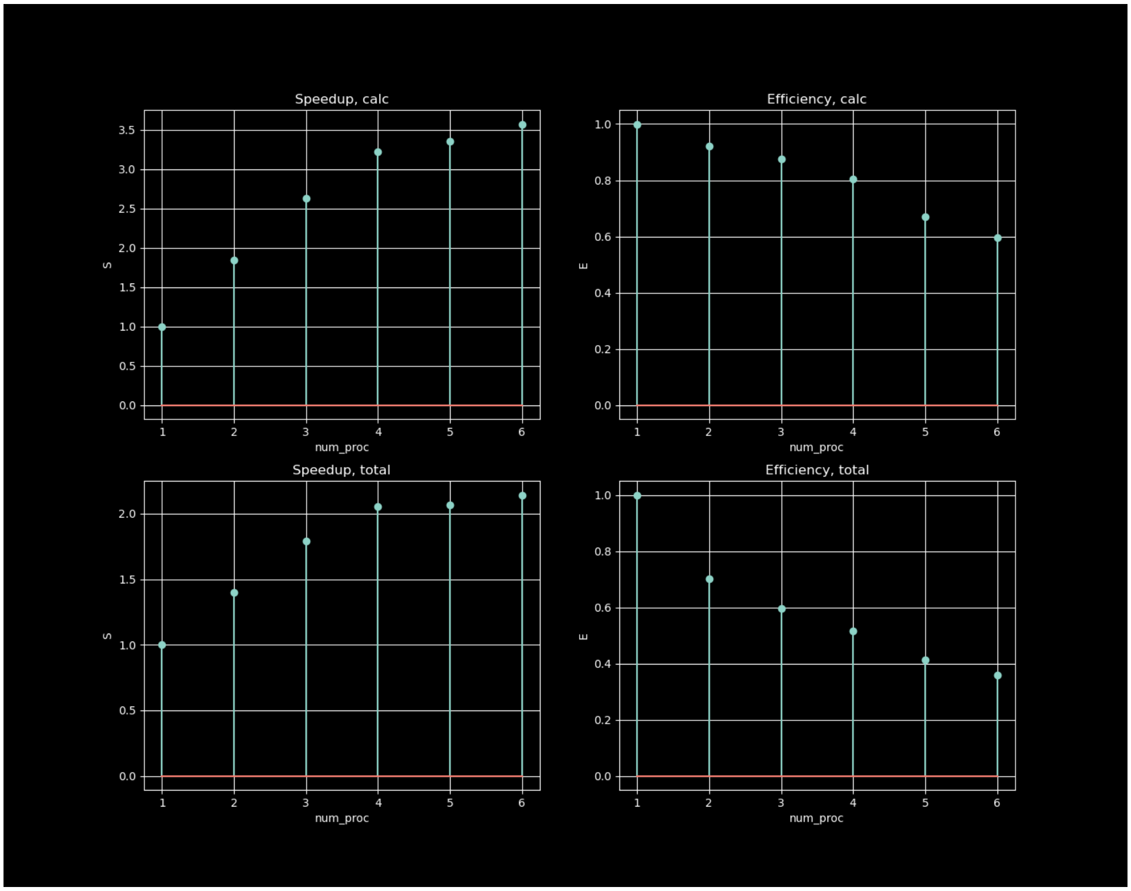
```
[ ]: <StemContainer object of 3 artists>
```



```
[ ]: # Speedup & efficiency for calc
     plt.figure (figsize = [14, 11])

     plt.subplot (221)
     plt.grid ()
     plt.title ("Speedup, calc")
     plt.xlabel ("num_proc")
     plt.ylabel ("S")
     plt.stem (np_var, times[0][0] / times[0])

     E = times[0][0] / times[0]
     for i in range (np_start, np_end + 1):
         E[i - np_start] = E[i - np_start] / i
```

```
plt.subplot (222)
plt.grid ()
plt.title ("Efficiency, calc")
plt.xlabel ("num_proc")
plt.ylabel ("E")
plt.stem (np_var, E)

plt.subplot (223)
plt.grid ()
plt.title ("Speedup, total")
plt.xlabel ("num_proc")
plt.ylabel ("S")
plt.stem (np_var, times[2][0] / times[2])

E = times[2][0] / times[2]
for i in range (np_start, np_end + 1):
    E[i - np_start] = E[i - np_start] / i
plt.subplot (224)
plt.grid ()
plt.title ("Efficiency, total")
plt.xlabel ("num_proc")
plt.ylabel ("E")
plt.stem (np_var, E)
```

```
[ ]: <StemContainer object of 3 artists>
```

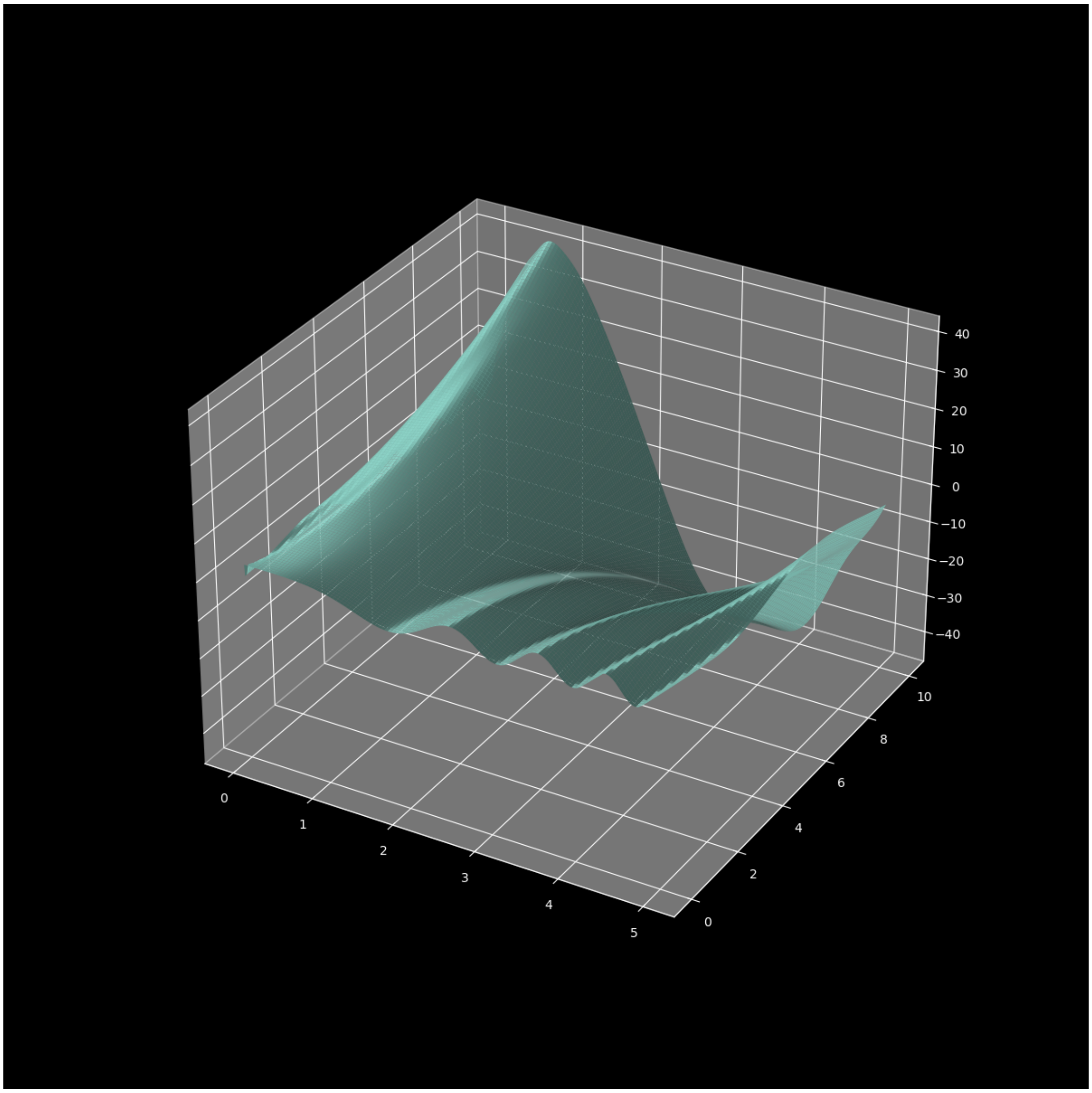


```
[ ]: #### CLUSTER through ssh ####
     import time
     n_proc = 4
     np_start = 1
     np_end = 32

     matrix = np.zeros ((x_points, x_points))
     perf_ranks = np.zeros ((n_proc, 3))
     compile = subprocess.run (["sshpass", "-p", "omeunzimarod", "ssh", "-o␣
      ↪StrictHostKeyChecking=no", "-p", "52960", "b0190302@remote.vdi.mipt.ru",␣
      ↪"make", "NUM_PROC={0}".format (n_proc), "ARGS=\"", "{0}".format (x_points),␣
      ↪"{0}".format (t_points), "{0}".format (x_max), "{0}".format (t_max), "{0}".
      ↪format (t_points - x_points), "{0}\"".format (t_points) , "-C", "./lab1/"])
     #print (compile)
     time.sleep (2)
     run = subprocess.run (["sshpass", "-p", "omeunzimarod", "ssh", "-o␣
      ↪StrictHostKeyChecking=no", "-p", "52960", "b0190302@remote.vdi.mipt.ru",␣
      ↪"make", "-C", "./lab1/", "run"])
     time.sleep (4)
```

```
result = subprocess.run (["sshpass", "-p", "omeunzimarod", "ssh", "-o␣
↪StrictHostKeyChecking=no", "-p", "52960", "b0190302@remote.vdi.mipt.ru",␣
↪"cat", "./lab1/stdout.txt"], capture_output=True, text=True)
res_split = result.stdout.split ()
for i in range (0, x_points):
    for j in range (0, x_points):
        matrix[i][j] = res_split[i * x_points + j]
for i in range (0, n_proc):
    rank = res_split[x_points * x_points + i * 4]
    for j in range (0, 3):
        perf_ranks[int (rank)][j] = res_split[x_points * x_points + i * 4 + j +␣
↪1]
#print ("last layer :")
#print (matrix[x_points - 1])

tabledata = []
for i in range (0, n_proc):
    temp = []
    temp.append (i)
    temp.append (perf_ranks[i][0])
    temp.append (perf_ranks[i][1])
    temp.append (perf_ranks[i][2])
    tabledata.append (temp)
print (tabulate (tabledata, headers = ["rank", "calc time", "gather time",␣
↪"total time"]))

X = np.outer (np.linspace (0, x_max, x_points), np.ones (x_points)).copy().T
T = np.outer (np.linspace (0, t_max, x_points), np.ones (x_points))
plt.figure(figsize=(12, 12))
plt.axes(projection ='3d').plot_surface (X, T, matrix, rcount = plt_rcount,␣
↪ccount = plt_ccount)
```

```
make: Entering directory `/home/b0190302/lab1'
mpic++ "-std=c++11"  -o Lab1  main.cpp
echo -e "\043PBS -l "walltime=00:01:00" \n\043PBS -N Lab1 \n\043PBS -q batch
\ncd \044PBS_O_WORKDIR \nmpirun --hostfile \044PBS_NODEFILE "-np 4"  ./Lab1 512
512 5 10 0 512"    > job.sh
make: Leaving directory `/home/b0190302/lab1'
make: Entering directory `/home/b0190302/lab1'
qsub -o stdout.txt ./job.sh
155947.head.vdi.mipt.ru
make: Leaving directory `/home/b0190302/lab1'
  rank    calc time    gather time    total time
------  -----------  -------------  ------------
     0    0.0134721     0.00531197      0.297298
     1    0.013165      0.00273681      0.015923
     2    0.013401      0.00372314      0.017143
     3     0.0131662     0.00470901     0.0178909
```

[ ]:
```
<mpl_toolkits.mplot3d.art3d.Poly3DCollection at 0x7f13c6bed3f0>
```

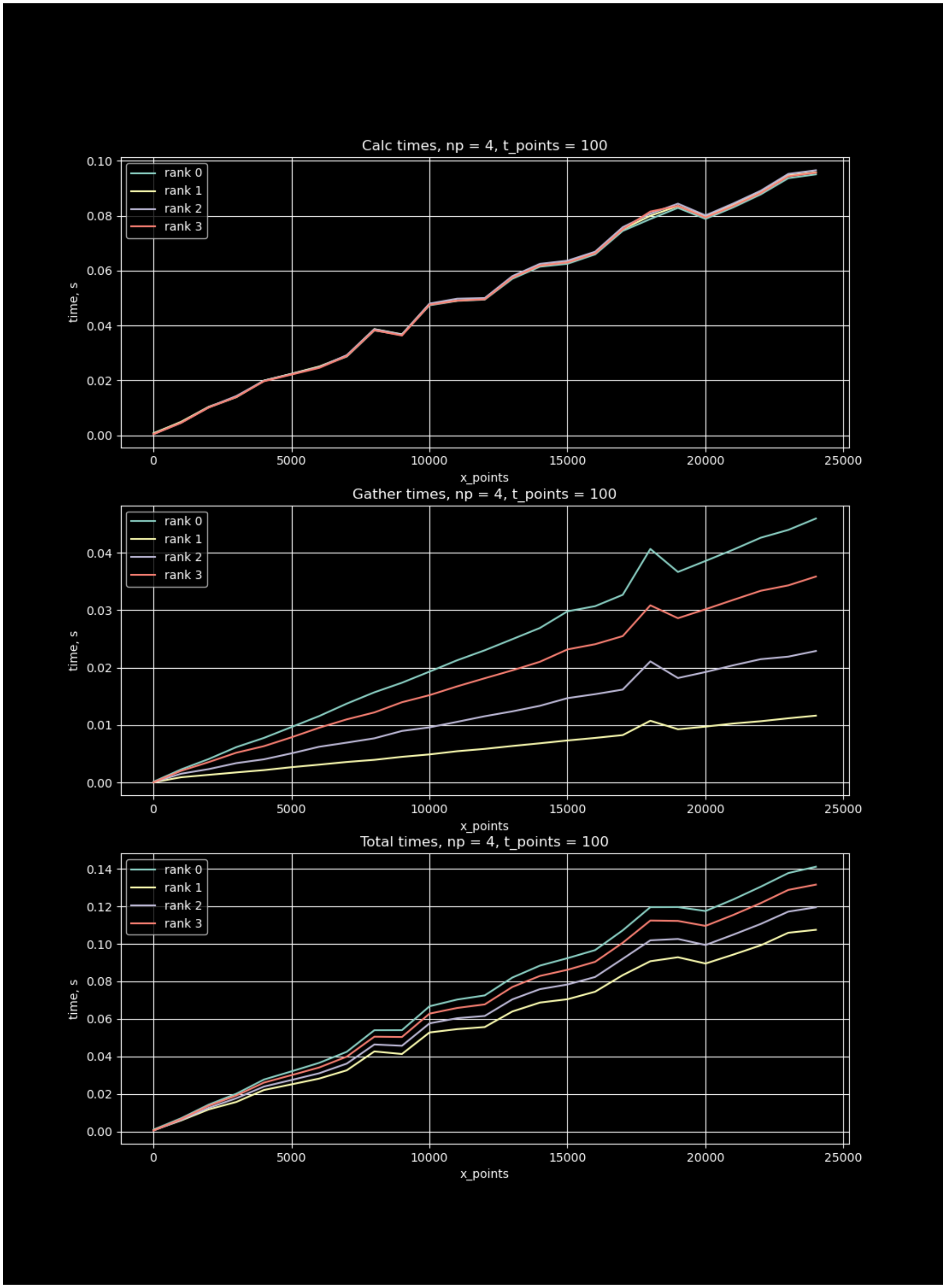


[ ]:
```
### x_points var at cluster

x_points_var = np.zeros (int ((x_points_end - x_points_start) / x_var_step) + 1)
times = np.zeros ((3, n_proc, int ((x_points_end - x_points_start) /␣
 ↪x_var_step) + 1))
i = x_points_start
k = 0
tabledata = []
with tqdm(total=int ((x_points_end - x_points_start) / x_var_step) + 1) as pbar:
    while i < x_points_end:
        compile = subprocess.run (["sshpass", "-p", "omeunzimarod", "ssh", "-o␣
 ↪StrictHostKeyChecking=no", "-p", "52960", "b0190302@remote.vdi.mipt.ru",␣
 ↪"make", "NUM_PROC={0}".format (n_proc), "ARGS=\"", "{0}".format (i), "{0}".
 ↪format (t_points_at_x_var), "{0}".format (x_max), "{0}".format (t_max),␣
 ↪"n\"", "-C", "./lab1/"], capture_output=True)
        time.sleep (2)
        #print (compile)
        run = subprocess.run (["sshpass", "-p", "omeunzimarod", "ssh", "-o␣
 ↪StrictHostKeyChecking=no", "-p", "52960", "b0190302@remote.vdi.mipt.ru",␣
 ↪"make", "-C", "./lab1/", "run"], capture_output=True)
        time.sleep (4)
        result = subprocess.run (["sshpass", "-p", "omeunzimarod", "ssh", "-o␣
 ↪StrictHostKeyChecking=no", "-p", "52960", "b0190302@remote.vdi.mipt.ru",␣
 ↪"cat", "./lab1/stdout.txt"], capture_output=True, text=True)
        #print (result)
        res_split = result.stdout.split ()
        times_max = np.zeros (3)
        for p in range (0, n_proc):
            rank = int (res_split[p * 4])
            for j in range (0, 3):
                times[j][rank][k] = res_split[p * 4 + j + 1]
                if times[j][rank][k] > times_max[j]:
                    times_max[j] = times[j][rank][k]
        x_points_var[k] = i
        temp = []
        temp.append (i)
        temp.append (times_max[0])
        temp.append (times_max[1])
        temp.append (times_max[2])
        tabledata.append (temp)
        i = i + x_var_step
        k = k + 1
        pbar.update (1)

print (tabulate (tabledata, headers = ["x_points", "max calc time", "max gather␣
 ↪time", "max total time"]))

plt.figure (figsize = [11, 15])

plt.subplot (311)
plt.grid ()
plt.title ("Calc times, np = {0}, t_points = {1}".format(n_proc,␣
 ↪t_points_at_x_var))
plt.xlabel ("x_points")
plt.ylabel ("time, s")
for i in range(0, n_proc):
    plt.plot (x_points_var, times[0][i], 'C{0}'.format (i), label = 'rank {0}'.
  ↪format(i))
plt.legend ()

plt.subplot (312)
plt.grid ()
plt.title ("Gather times, np = {0}, t_points = {1}".format(n_proc,␣
  ↪t_points_at_x_var))
plt.xlabel ("x_points")
plt.ylabel ("time, s")
for i in range(0, n_proc):
    plt.plot (x_points_var, times[1][i], 'C{0}'.format (i), label = 'rank {0}'.
  ↪format(i))
plt.legend ()

plt.subplot (313)
plt.grid ()
plt.title ("Total times, np = {0}, t_points = {1}".format(n_proc,␣
  ↪t_points_at_x_var))
plt.xlabel ("x_points")
plt.ylabel ("time, s")
for i in range(0, n_proc):
    plt.plot (x_points_var, times[2][i], 'C{0}'.format (i), label = 'rank {0}'.
  ↪format(i))
plt.legend ()
```

```
100%|      | 25/25 [03:38<00:00,  8.73s/it]

  x_points    max calc time    max gather time    max total time
----------  ---------------  -----------------  ----------------
         6       0.00079298        0.000123024       0.000936985
      1006       0.00491881        0.00227284        0.00703502
      2006       0.0103929         0.00408411        0.014293
      3006       0.0142961         0.00615811        0.020083
      4006       0.0199261         0.00775981        0.0276458
      5006       0.0224171         0.0096581         0.032033
      6006       0.0250411         0.0115659         0.0365431
      7006       0.0291829         0.0137291         0.0424421
      8006       0.0386829         0.0157049         0.053952
      9006       0.0367801         0.0173731         0.0539789
     10006       0.0479822         0.0193119         0.0667241
     11006       0.049767          0.0212848         0.070292
     12006       0.049998          0.0230269         0.0725169
     13006       0.057986          0.0249591         0.082026
     14006       0.0624659         0.026916          0.0883958
     15006       0.063612          0.029819          0.0923641
     16006       0.0668879         0.0307131         0.0966718
```

```
    17006       0.0758159         0.032692          0.107207
    18006       0.081527          0.0406859         0.11954
    19006       0.084388          0.0366731         0.119595
    20006       0.0801101         0.0385919         0.117501
    21006       0.0844262         0.0405521         0.123635
    22006       0.0890992         0.0426381         0.130467
    23006       0.095232          0.044003          0.137745
    24006       0.096549          0.0459859         0.141119
```

```
[ ]: <matplotlib.legend.Legend at 0x7f13c6b060e0>
```

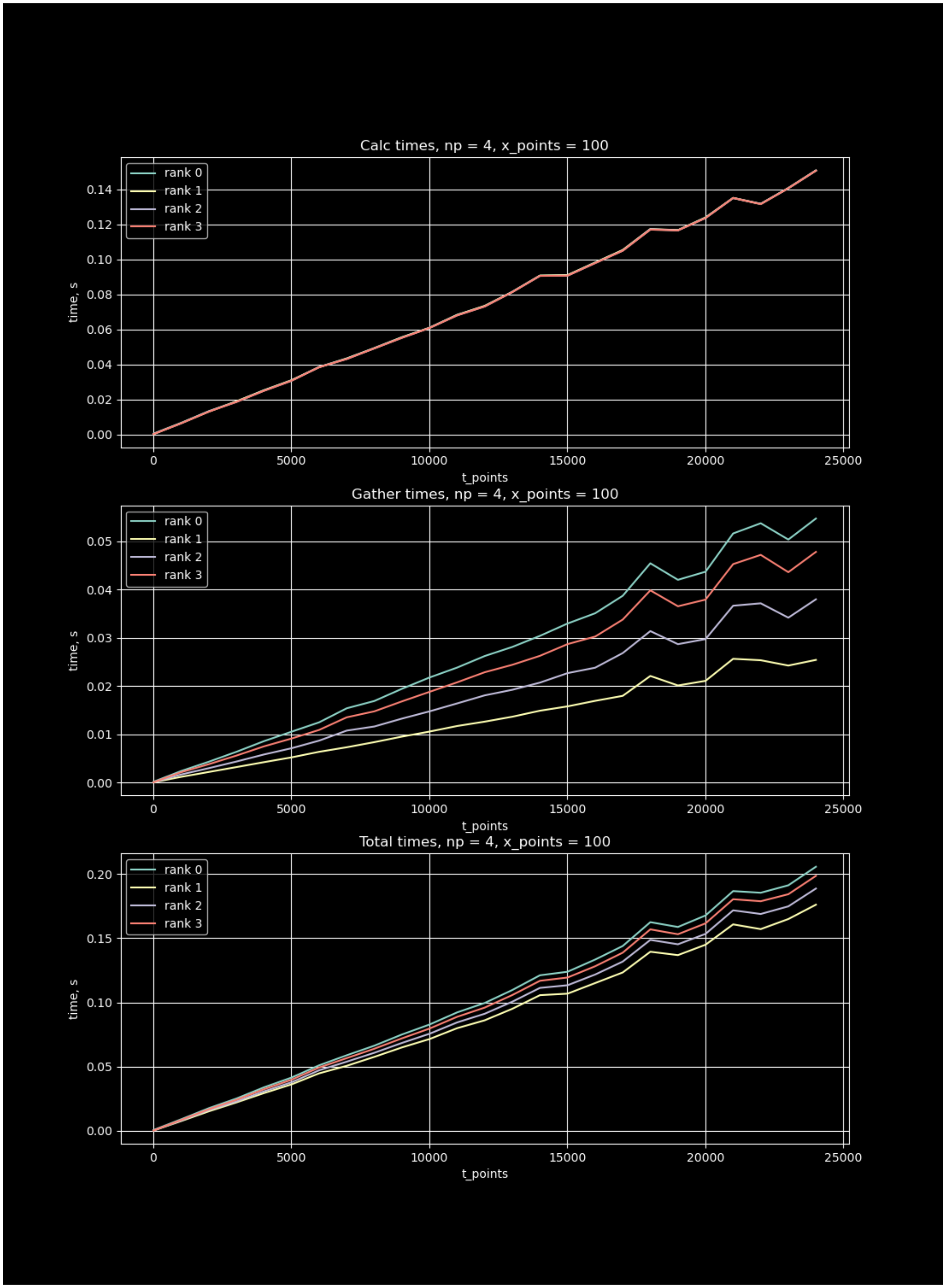

Calc times, np = 4, t_points = 100
rank 0
rank 1
rank 2
rank 3
time, s
0.00
0.02
0.04
0.06
0.08
0.10
0
5000
10000
15000
20000
25000
x_points
Gather times, np = 4, t_points = 100
rank 0
rank 1
rank 2
rank 3
time, s
0.00
0.01
0.02
0.03
0.04
0
5000
10000
15000
20000
25000
x_points
Total times, np = 4, t_points = 100
rank 0
rank 1
rank 2
rank 3
time, s
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
5000
10000
15000
20000
25000
x_points

```
[ ]: ### t_points var at cluster

t_points_var = np.zeros (int ((t_points_end - t_points_start) / t_var_step) + 1)
times = np.zeros ((3, n_proc, int ((t_points_end - t_points_start) /␣
 ↪t_var_step) + 1))
i = t_points_start
k = 0
tabledata = []
with tqdm(total=int ((t_points_end - t_points_start) / t_var_step) + 1) as pbar:
    while i < t_points_end:
        compile = subprocess.run (["sshpass", "-p", "omeunzimarod", "ssh", "-o␣
 ↪StrictHostKeyChecking=no", "-p", "52960", "b0190302@remote.vdi.mipt.ru",␣
 ↪"make", "NUM_PROC={0}".format (n_proc), "ARGS=\"", "{0}".format␣
 ↪(x_points_at_t_var), "{0}".format (i), "{0}".format (x_max), "{0}".format␣
 ↪(t_max), "n\"", "-C", "./lab1/"], capture_output=True)
        time.sleep (2)
        run = subprocess.run (["sshpass", "-p", "omeunzimarod", "ssh", "-o␣
 ↪StrictHostKeyChecking=no", "-p", "52960", "b0190302@remote.vdi.mipt.ru",␣
 ↪"make", "-C", "./lab1/", "run"], capture_output=True)
        time.sleep (4)
        result = subprocess.run (["sshpass", "-p", "omeunzimarod", "ssh", "-o␣
 ↪StrictHostKeyChecking=no", "-p", "52960", "b0190302@remote.vdi.mipt.ru",␣
 ↪"cat", "./lab1/stdout.txt"], capture_output=True, text=True)
        res_split = result.stdout.split ()
        times_max = np.zeros (3)
        for p in range (0, n_proc):
            rank = int (res_split[p * 4])
            for j in range (0, 3):
                times[j][rank][k] = res_split[p * 4 + j + 1]
                if times[j][rank][k] > times_max[j]:
                    times_max[j] = times[j][rank][k]
        t_points_var[k] = i
        temp = []
        temp.append (i)
        temp.append (times_max[0])
        temp.append (times_max[1])
        temp.append (times_max[2])
        tabledata.append (temp)
        i = i + t_var_step
        k = k + 1
        pbar.update (1)

print (tabulate (tabledata, headers = ["t_points", "max calc time", "max gather␣
 ↪time", "max total time"]))

plt.figure (figsize = [11, 15])
plt.subplot (311)
plt.grid ()
plt.title ("Calc times, np = {0}, x_points = {1}".format(n_proc,␣
 ↪x_points_at_t_var))
plt.xlabel ("t_points")
plt.ylabel ("time, s")
for i in range(0, n_proc):
    plt.plot (t_points_var, times[0][i], 'C{0}'.format (i), label = 'rank {0}'.
 ↪format(i))
plt.legend ()

plt.subplot (312)
plt.grid ()
plt.title ("Gather times, np = {0}, x_points = {1}".format(n_proc,␣
 ↪x_points_at_t_var))
plt.xlabel ("t_points")
plt.ylabel ("time, s")
for i in range(0, n_proc):
    plt.plot (t_points_var, times[1][i], 'C{0}'.format (i), label = 'rank {0}'.
 ↪format(i))
plt.legend ()

plt.subplot (313)
plt.grid ()
plt.title ("Total times, np = {0}, x_points = {1}".format(n_proc,␣
 ↪x_points_at_t_var))
plt.xlabel ("t_points")
plt.ylabel ("time, s")
for i in range(0, n_proc):
    plt.plot (t_points_var, times[2][i], 'C{0}'.format (i), label = 'rank {0}'.
 ↪format(i))
plt.legend ()
```

```
100%|     | 25/25 [03:24<00:00,  8.18s/it]

  t_points    max calc time    max gather time    max total time
----------  ---------------  -----------------  ----------------
        10      0.000478983        0.000128984       0.000633001
      1010      0.00660992         0.00236082        0.0089972
      2010      0.0132899          0.00428391        0.0176132
      3010      0.0189009          0.00634193        0.0251329
      4010      0.025275           0.00855398        0.0338681
      5010      0.0309598          0.0105209         0.0414779
      6010      0.0385189          0.012464          0.0510218
      7010      0.0434198          0.015379          0.05884
      8010      0.0493691          0.016891          0.0663049
      9010      0.0555398          0.0194221         0.075017
```

```
10010      0.0609541          0.0217669        0.082777
11010      0.068347           0.0238259        0.0922229
12010      0.0734351          0.026221         0.0995641
13010      0.0815032          0.0281088        0.10966
14010      0.0907209          0.030407         0.121115
15010      0.0909979          0.0329649        0.123874
16010      0.0981958          0.0350912        0.13334
17010      0.105338           0.038723         0.143925
18010      0.117328           0.0454609        0.162479
19010      0.116671           0.0420339        0.15872
20010      0.12392            0.043716         0.1677
21010      0.135077           0.0516531        0.18667
22010      0.131683           0.0537729        0.185385
23010      0.140733           0.0503881        0.191175
24010      0.150827           0.0547571        0.205639
```

```
[ ]: <matplotlib.legend.Legend at 0x7f13bf3bd780>
```


Calc times, np = 4, x_points = 100
rank 0
rank 1
rank 2
rank 3
time, s
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
5000
10000
15000
20000
25000
t_points
Gather times, np = 4, x_points = 100
rank 0
rank 1
rank 2
rank 3
time, s
0.00
0.01
0.02
0.03
0.04
0.05
0
5000
10000
15000
20000
25000
t_points
Total times, np = 4, x_points = 100
rank 0
rank 1
rank 2
rank 3
time, s
0.00
0.05
0.10
0.15
0.20
0
5000
10000
15000
20000
25000
t_points

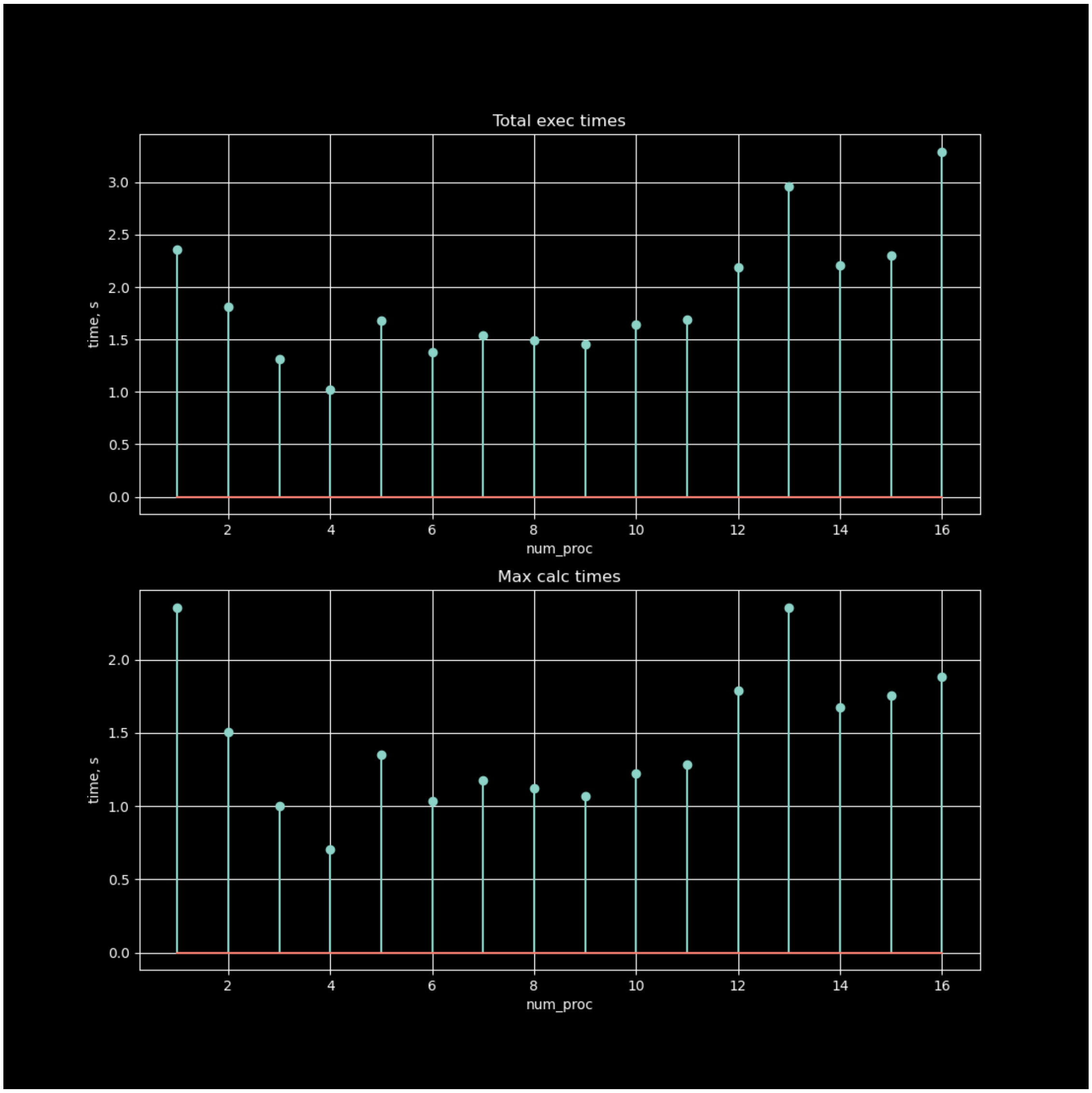
[ ]:

```
### np var at cluster
np_end = 16
np_var = np.arange (np_start, np_end + 1)
times = np.zeros ((3, np_end - np_start + 1))
i = np_start
tabledata = []
with tqdm(total = np_end - np_start + 1) as pbar:
    while i <= np_end:
        compile = subprocess.run (["sshpass", "-p", "omeunzimarod", "ssh", "-o␣
 ↪StrictHostKeyChecking=no", "-p", "52960", "b0190302@remote.vdi.mipt.ru",␣
 ↪"make", "NUM_PROC={0}".format (i), "ARGS=\"", "{0}".format␣
 ↪(x_points_at_np_var), "{0}".format (t_points_at_np_var), "{0}".format␣
 ↪(x_max), "{0}".format (t_max), "n\"", "-C", "./lab1/"], capture_output=True)
        time.sleep (2)
        run = subprocess.run (["sshpass", "-p", "omeunzimarod", "ssh", "-o␣
 ↪StrictHostKeyChecking=no", "-p", "52960", "b0190302@remote.vdi.mipt.ru",␣
 ↪"make", "-C", "./lab1/", "run"], capture_output=True)
        time.sleep (6)
        result = subprocess.run (["sshpass", "-p", "omeunzimarod", "ssh", "-o␣
 ↪StrictHostKeyChecking=no", "-p", "52960", "b0190302@remote.vdi.mipt.ru",␣
 ↪"cat", "./lab1/stdout.txt"], capture_output=True, text=True)
        res_split = result.stdout.split ()
        max_calc = 0
        max_gather = 0
        max_total = 0
        for p in range (0, i - np_start + 1):
            if float (res_split[p * 4 + 1]) > max_calc:
                max_calc = float (res_split[p * 4 + 1])
            if float (res_split[p * 4 + 2]) > max_gather:
                max_gather = float (res_split[p * 4 + 2])
            if float (res_split[p * 4 + 3]) > max_total:
                max_total = float (res_split[p * 4 + 3])

        times[0][i - np_start] = max_calc
        times[1][i - np_start] = max_gather
        times[2][i - np_start] = max_total
        temp = []
        temp.append (i)
        temp.append (max_calc)
        temp.append (max_gather)
        temp.append (max_total)
        tabledata.append (temp)
        i = i + 1
        pbar.update (1)

print (tabledata, headers = ["N proc", "max calc time", "max gather␣
 ↪time", "max total time"]))
```

```
plt.figure (figsize = [11, 11])

plt.subplot (211)
plt.grid ()
plt.title ("Total exec times")
plt.xlabel ("num_proc")
plt.ylabel ("time, s")
plt.stem (np_var, times[2])

plt.subplot (212)
plt.grid ()
plt.title ("Max calc times")
plt.xlabel ("num_proc")
plt.ylabel ("time, s")
plt.stem (np_var, times[0])
```

```
100%|        | 16/16 [02:45<00:00, 10.35s/it]

  N proc    max calc time    max gather time    max total time
--------  ---------------  -----------------  ----------------
       1          2.35508           0                  2.35511
       2          1.50745           0.305542           1.81267
       3          0.998122          0.313425           1.31146
       4          0.700828          0.324271           1.02495
       5          1.35209           0.32725            1.67875
       6          1.03358           0.349518           1.38256
       7          1.17583           0.367629           1.54274
       8          1.11881           0.374073           1.49195
       9          1.06772           0.384765           1.45134
      10          1.22462           0.417249           1.64119
      11          1.28648           0.407616           1.69234
      12          1.79185           0.396272           2.18559
      13          2.35839           0.598838           2.95582
      14          1.67388           0.536139           2.20793
      15          1.7529            0.548369           2.29771
      16          1.88086           1.42573            3.29432
```

```
[ ]: <StemContainer object of 3 artists>
```

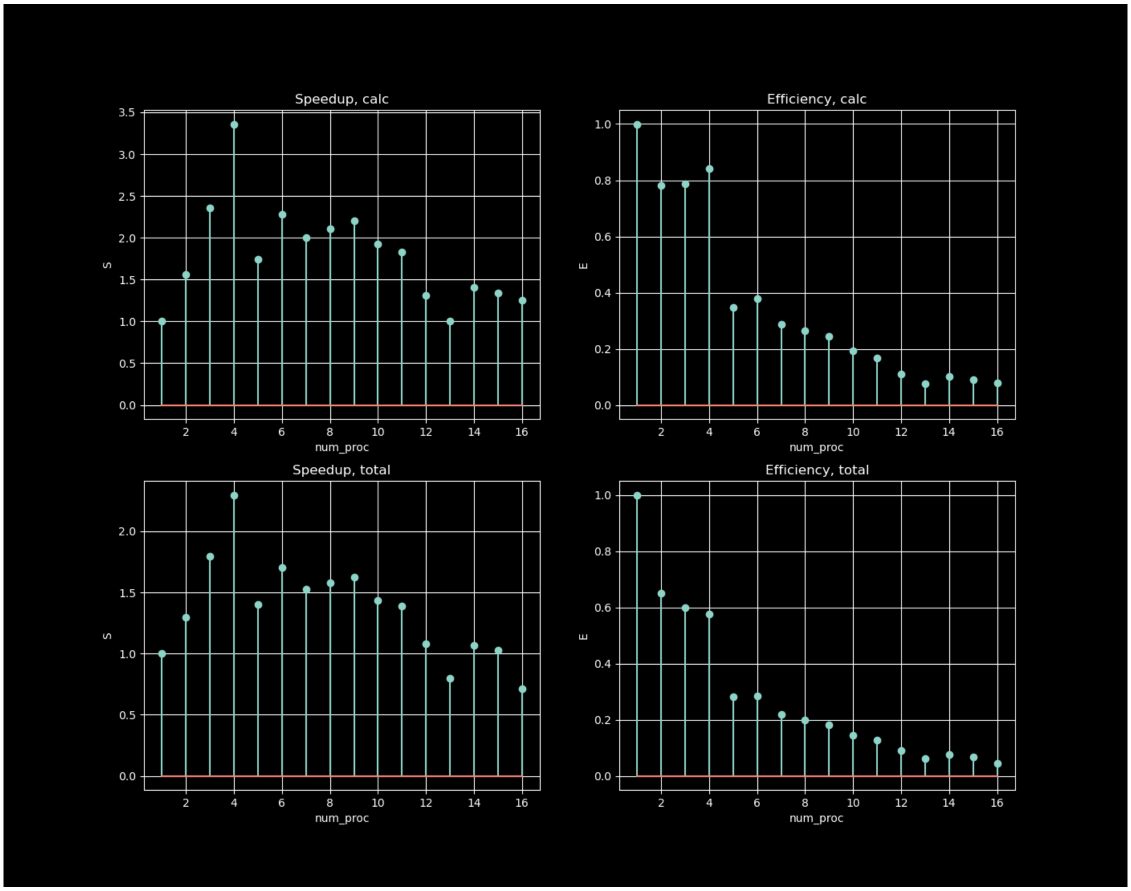


[ ]:

```
# Speedup & efficiency for calc
plt.figure (figsize = [14, 11])

plt.subplot (221)
plt.grid ()
plt.title ("Speedup, calc")
plt.xlabel ("num_proc")
plt.ylabel ("S")
plt.stem (np_var, times[0][0] / times[0])

E = times[0][0] / times[0]
for i in range (np_start, np_end + 1):
    E[i - np_start] = E[i - np_start] / i
```

```python
plt.subplot (222)
plt.grid ()
plt.title ("Efficiency, calc")
plt.xlabel ("num_proc")
plt.ylabel ("E")
plt.stem (np_var, E)

plt.subplot (223)
plt.grid ()
plt.title ("Speedup, total")
plt.xlabel ("num_proc")
plt.ylabel ("S")
plt.stem (np_var, times[2][0] / times[2])

E = times[2][0] / times[2]
for i in range (np_start, np_end + 1):
    E[i - np_start] = E[i - np_start] / i
plt.subplot (224)
plt.grid ()
plt.title ("Efficiency, total")
plt.xlabel ("num_proc")
plt.ylabel ("E")
plt.stem (np_var, E)
```

```
[ ]: <StemContainer object of 3 artists>
```


Speedup, calc
S
num_proc
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2
4
6
8
10
12
14
16
Efficiency, calc
E
num_proc
1.0
0.8
0.6
0.4
0.2
0.0
Speedup, total
S
num_proc
2.0
1.5
1.0
0.5
0.0
Efficiency, total
E
num_proc
1.0
0.8
0.6
0.4
0.2
0.0