

benchmark_analysis

March 14, 2023

1 Benchmark Analysis

```
[1]: import sys
      !{sys.executable} -m pip install -r requirements.txt
```

```
Requirement already satisfied: matplotlib in /opt/homebrew/lib/python3.11/site-
packages (from -r requirements.txt (line 1)) (3.7.0)
Requirement already satisfied: numpy in /opt/homebrew/lib/python3.11/site-
packages (from -r requirements.txt (line 2)) (1.24.2)
Requirement already satisfied: pandas in /opt/homebrew/lib/python3.11/site-
packages (from -r requirements.txt (line 3)) (1.5.3)
Requirement already satisfied: contourpy>=1.0.1 in
/opt/homebrew/lib/python3.11/site-packages (from matplotlib->-r requirements.txt
(line 1)) (1.0.7)
Requirement already satisfied: cycler>=0.10 in
/opt/homebrew/lib/python3.11/site-packages (from matplotlib->-r requirements.txt
(line 1)) (0.11.0)
Requirement already satisfied: fonttools>=4.22.0 in
/opt/homebrew/lib/python3.11/site-packages (from matplotlib->-r requirements.txt
(line 1)) (4.38.0)
Requirement already satisfied: kiwisolver>=1.0.1 in
/opt/homebrew/lib/python3.11/site-packages (from matplotlib->-r requirements.txt
(line 1)) (1.4.4)
Requirement already satisfied: packaging>=20.0 in
/opt/homebrew/Cellar/jupyterlab/3.4.8_1/libexec/lib/python3.11/site-packages
(from matplotlib->-r requirements.txt (line 1)) (21.3)
Requirement already satisfied: pillow>=6.2.0 in
/opt/homebrew/lib/python3.11/site-packages (from matplotlib->-r requirements.txt
(line 1)) (9.4.0)
Requirement already satisfied: pyparsing>=2.3.1 in
/opt/homebrew/Cellar/jupyterlab/3.4.8_1/libexec/lib/python3.11/site-packages
(from matplotlib->-r requirements.txt (line 1)) (3.0.9)
Requirement already satisfied: python-dateutil>=2.7 in
/opt/homebrew/Cellar/jupyterlab/3.4.8_1/libexec/lib/python3.11/site-packages
(from matplotlib->-r requirements.txt (line 1)) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in
/opt/homebrew/Cellar/jupyterlab/3.4.8_1/libexec/lib/python3.11/site-packages
(from pandas->-r requirements.txt (line 3)) (2022.4)
```

```
Requirement already satisfied: six>=1.5 in
/opt/homebrew/opt/six/lib/python3.11/site-packages (from python-
dateutil>=2.7->matplotlib->r requirements.txt (line 1)) (1.16.0)
```

```
[notice] A new release of pip
available: 22.3.1 -> 23.0.1
[notice] To update, run:
python3.11 -m pip install --upgrade pip
```

```
[2]: import matplotlib
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import statistics
import os
from pathlib import Path
from typing import List, Dict, Any

%matplotlib inline
```

```
[3]: matplotlib.style.use('seaborn-v0_8')
```

```
[4]: root_dir = '/Users/diego/Desktop/BENCHMARK_NEBULAC_ALL'
```

```
[5]: GCC_TBB_COLOR = 'salmon'
GCC_TBB_COLOR_SECONDARY = 'sienna'

NVC_OMP_COLOR = 'green'
NVC_OMP_COLOR_SECONDARY = 'yellowgreen'

NVC_GPU_COLOR = 'beige'
```

1.1 Utils

```
[6]: def get_path(*entries):
    return os.path.join(*entries)
```

```
[7]: def ensure_file_existence(output_filename):
    """
    Checks whether the path to the file exists. If not it creates the folder_
    structure and the final file.
    :param output_filename: path to the file
    :return:
    """

    # creates dirs etc if they do not exists
    output_path = Path(output_filename)
    if not os.path.exists(output_path.parent):
```

```

        os.makedirs(output_path.parent)
        output_path.touch(exist_ok=True) # will create file, if it exists will do
↳ nothing

```

```

[8]: def extraction_pandas_frame_algo(path, COMP="TODO"):
    df = pd.read_csv(path)

    # dropping columns we do not care about
    df = df.drop(['iterations', 'bytes_per_second', 'items_per_second',
↳ 'label', 'error_occurred', 'error_message'],
                axis=1)

    # adding the problem size as column
    df = df[df['name'].str.endswith(('mean', 'median', 'stddev'))]
    df['n'] = df.apply(lambda x: x[0][x[0].find('/') + 1:x[0].rfind('_')],
↳ axis=1)

    df = df.reset_index(drop=True)

    # convert to format
    #
↳ name          real_time          cpu_time          time_unit          n          median          stddev
    results_gcc = df.groupby('n').apply(lambda sf: pd.Series(sf.iloc[0])).
↳ reset_index(drop=True)
    results_gcc.n = results_gcc.n.astype(int)
    results_gcc = results_gcc.sort_values(['n'], ascending=True).
↳ reset_index(drop=True)

    results_gcc['C'] = np.arange(len(results_gcc))

    results_gcc['median_id'] = results_gcc['C'] * 3 + 1
    results_gcc['median'] = results_gcc['median_id'].apply(lambda x: df.
↳ iloc[x]['real_time'])

    results_gcc['stddev_id'] = results_gcc['C'] * 3 + 2
    results_gcc['stddev'] = results_gcc['stddev_id'].apply(lambda x: df.
↳ iloc[x]['real_time'])

    results_gcc = results_gcc.drop(['C', 'median_id', 'stddev_id'], axis=1)
    results_gcc['Compiler'] = COMP
    results_gcc['name'] = results_gcc.apply(lambda x: x[0].replace(str(x['n']),
↳ "").replace('/_mean', ''), axis=1)

    return results_gcc

```

```
[9]: # generate filename for threading
def get_threading_file_name(benchmark_name:str, thread_nr: int, input_size:str) → str:
    return f"[T{thread_nr}]_{benchmark_name}_{input_size}_T{thread_nr}.csv"

# extract threaded into dictionary
def extraction_pandas_frame_algo_threaded(folder_path:str, benchmark_name:str, threads_list:List[int], input_size:int = '1048576', COMP:str="TODO") → Any:
    result = pd.DataFrame()

    for t_id in threads_list:
        filename = get_threading_file_name(benchmark_name=benchmark_name, thread_nr=t_id, input_size=input_size)
        file_path = get_path(folder_path,filename)

        data_frame = extraction_pandas_frame_algo(file_path,COMP=COMP)
        data_frame['threads'] = t_id
        result = pd.concat([result, data_frame], ignore_index=True)

    result = result.rename_axis(None, axis=1)
    return result
```

```
[10]: # calculate speedup based on seq runnings
def calc_speedup_based_seq(seq_df: pd.DataFrame, threads_df: pd.DataFrame, speedup_column_name:str, input_size:int = 1048576) → pd.DataFrame:
    # calculate speedup
    seq_df = seq_df[seq_df['n'] == input_size]
    seq_time = seq_df['real_time'].iloc[0] # now its only a single digit

    threads_df['speedup'] = seq_time / threads_df['real_time']

    # clean df
    threads_df = threads_df.drop(columns=['name', 'cpu_time', 'time_unit', 'median', 'stddev', 'Compiler', 'n', 'real_time'])
    threads_df = threads_df.rename(columns={'speedup':speedup_column_name})

    return threads_df
```

```
[11]: def calc_speedup_based_par(threads_df: pd.DataFrame, speedup_column_name:str, input_size:int = 1048576) → pd.DataFrame:
    base_time = threads_df[threads_df['threads'] == 1].iloc[0]['real_time']

    threads_df['speedup'] = base_time / threads_df['real_time']

    # clean df
```

```

    threads_df = threads_df.
↳ drop(columns=['name', 'cpu_time', 'time_unit', 'median', 'stddev', 'Compiler', 'n', 'real_time'])
    threads_df = threads_df.rename(columns={'speedup': speedup_column_name})

    return threads_df

```

2 Nebulah all Core

```

Architecture:      x86_64
CPU op-mode(s):    32-bit, 64-bit
Byte Order:        Little Endian
Address sizes:      43 bits physical, 48 bits virtual
CPU(s):            64
On-line CPU(s) list: 0-63
Thread(s) per core: 1
Core(s) per socket: 32
Socket(s):          2
NUMA node(s):      8
Vendor ID:          AuthenticAMD
CPU family:         23
Model:             1
Model name:         AMD EPYC 7551 32-Core Processor
Stepping:           2
CPU MHz:            2404.199
CPU max MHz:        2000.0000
CPU min MHz:        1200.0000
BogoMIPS:           3992.24
Virtualization:     AMD-V
L1d cache:          32K
L1i cache:          64K
L2 cache:           512K
L3 cache:           8192K
NUMA node0 CPU(s): 0,8,16,24,32,40,48,56
NUMA node1 CPU(s): 2,10,18,26,34,42,50,58
NUMA node2 CPU(s): 4,12,20,28,36,44,52,60
NUMA node3 CPU(s): 6,14,22,30,38,46,54,62
NUMA node4 CPU(s): 1,9,17,25,33,41,49,57
NUMA node5 CPU(s): 3,11,19,27,35,43,51,59
NUMA node6 CPU(s): 5,13,21,29,37,45,53,61
NUMA node7 CPU(s): 7,15,23,31,39,47,55,63
Flags:              fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 c

```

2.1 H1

Some parallel backends exhibit better performance and scalability when handling nested parallelism for homogeneous workloads

2.1.1 Time

Time Comparison - b1_1_for_each_linear_par Check how the runtime without constraining the threads develops with increasing input size

```
[12]: # load data gcc (b1_1_for_each_linear_par)
b1_1_for_each_linear_par_gcc = extraction_pandas_frame_algo(root_dir + '/'
↳GCC_TBB/DEFAULT/b1_1_for_each_linear_par__Default.csv',COMP="GCC(TBB)")

b1_1_for_each_linear_par_gcc = b1_1_for_each_linear_par_gcc.
↳drop(columns=['name', 'cpu_time', 'time_unit', 'median', 'stddev', 'Compiler'])
b1_1_for_each_linear_par_gcc = b1_1_for_each_linear_par_gcc.
↳rename(columns={'real_time': 'GCC(TBB)'})

# load data nvhpc (b1_1_for_each_linear_par)
b1_1_for_each_linear_par_nvc_omp = extraction_pandas_frame_algo(root_dir + '/'
↳NVHPC_Multicore/DEFAULT/b1_1_for_each_linear_par__Default.csv',
↳COMP="NVC(OMP)")

b1_1_for_each_linear_par_nvc_omp = b1_1_for_each_linear_par_nvc_omp.
↳drop(columns=['name', 'cpu_time', 'time_unit', 'median', 'stddev', 'Compiler'])
b1_1_for_each_linear_par_nvc_omp = b1_1_for_each_linear_par_nvc_omp.
↳rename(columns={'real_time': 'NVC(OMP)'})

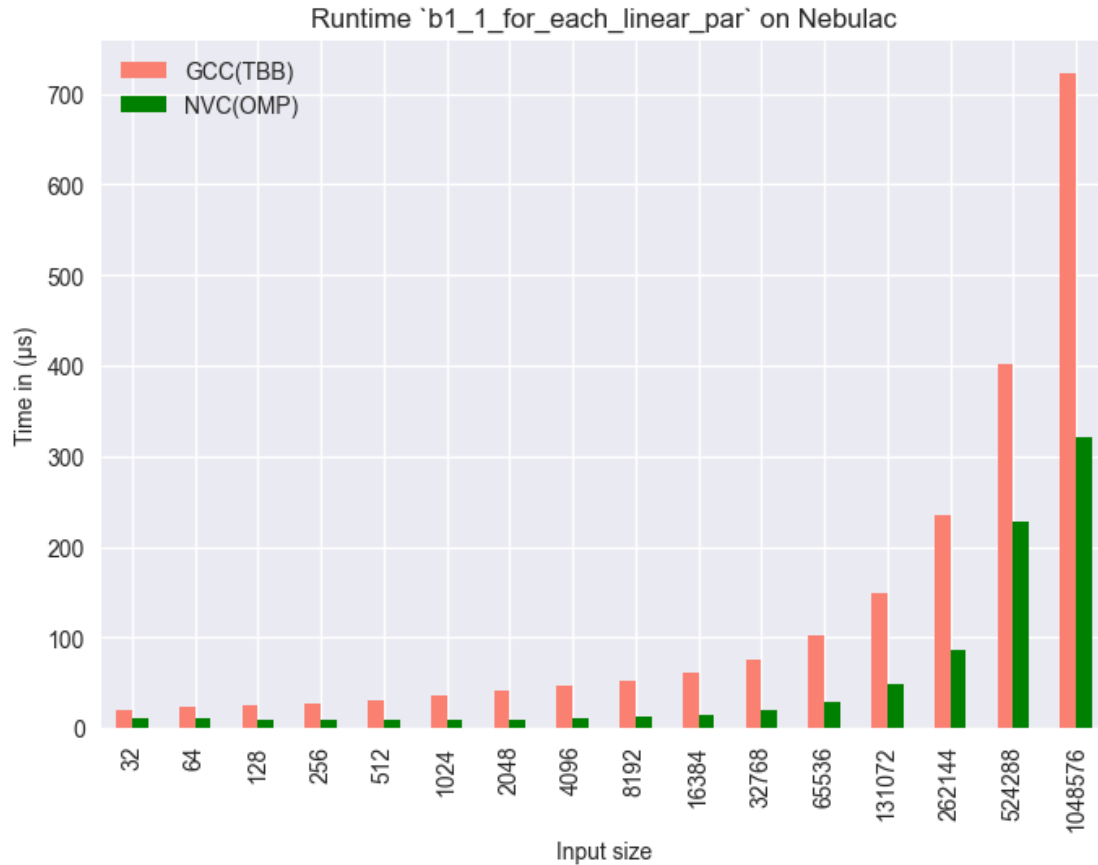
# merge for plotting
b1_1_for_each_linear_par_time_merged = pd.merge(b1_1_for_each_linear_par_gcc,
↳b1_1_for_each_linear_par_nvc_omp, on='n')
b1_1_for_each_linear_par_time_merged

# convert time from ns to microseconds because otherwise it will look really bad
b1_1_for_each_linear_par_time_merged['GCC(TBB)'] =
↳b1_1_for_each_linear_par_time_merged['GCC(TBB)'] / 1_000
b1_1_for_each_linear_par_time_merged['NVC(OMP)'] =
↳b1_1_for_each_linear_par_time_merged['NVC(OMP)'] / 1_000

# plot
b1_1_for_each_linear_par_time_merged.
↳plot(kind='bar', x='n', align='center', color=[GCC_TBB_COLOR, NVC_OMP_COLOR])

plt.ylabel('Time in (µs)')
plt.xlabel('Input size')
plt.title('Runtime `b1_1_for_each_linear_par` on Nebulac')

plt.show()
```



Time Comparison - b1_2_for_each_quadratic_outer_std::execution::parallel_policy_par
 Check how the runtime without constraining the threads develops with increasing input size

```
[13]: # load data gcc (b1_2_for_each_quadratic_outer_std::execution::
      ↪parallel_policy_par)
b1_2_for_each_quadratic_par_par_gcc = extraction_pandas_frame_algo(root_dir + '/'
      ↪GCC_TBB/DEFAULT/b1_2_for_each_quadratic_outer_std::execution::
      ↪parallel_policy_par__Default.csv', COMP="GCC(TBB)")

b1_2_for_each_quadratic_par_par_gcc = b1_2_for_each_quadratic_par_par_gcc.
      ↪drop(columns=['name', 'cpu_time', 'time_unit', 'median', 'stddev', 'Compiler'])
b1_2_for_each_quadratic_par_par_gcc = b1_2_for_each_quadratic_par_par_gcc.
      ↪rename(columns={'real_time': 'GCC(TBB)'})

# load data nvhpc (b1_2_for_each_quadratic_outer_std::execution::
      ↪parallel_policy_par)
```

```

b1_2_for_each_quadratic_par_par_nvc_omp = extraction_pandas_frame_algo(root_dir,
↳+ '/NVHPC_Multicore/DEFAULT/b1_2_for_each_quadratic_outer_std::execution::
↳parallel_policy_par__Default.csv', COMP="NVC(OMP)")

b1_2_for_each_quadratic_par_par_nvc_omp =
↳b1_2_for_each_quadratic_par_par_nvc_omp.
↳drop(columns=['name', 'cpu_time', 'time_unit', 'median', 'stddev', 'Compiler'])
b1_2_for_each_quadratic_par_par_nvc_omp =
↳b1_2_for_each_quadratic_par_par_nvc_omp.rename(columns={'real_time':
↳'NVC(OMP)'}))

# merge for plotting
b1_2_for_each_quadratic_par_par_time_merged = pd.
↳merge(b1_2_for_each_quadratic_par_par_gcc,
↳b1_2_for_each_quadratic_par_par_nvc_omp, on='n')

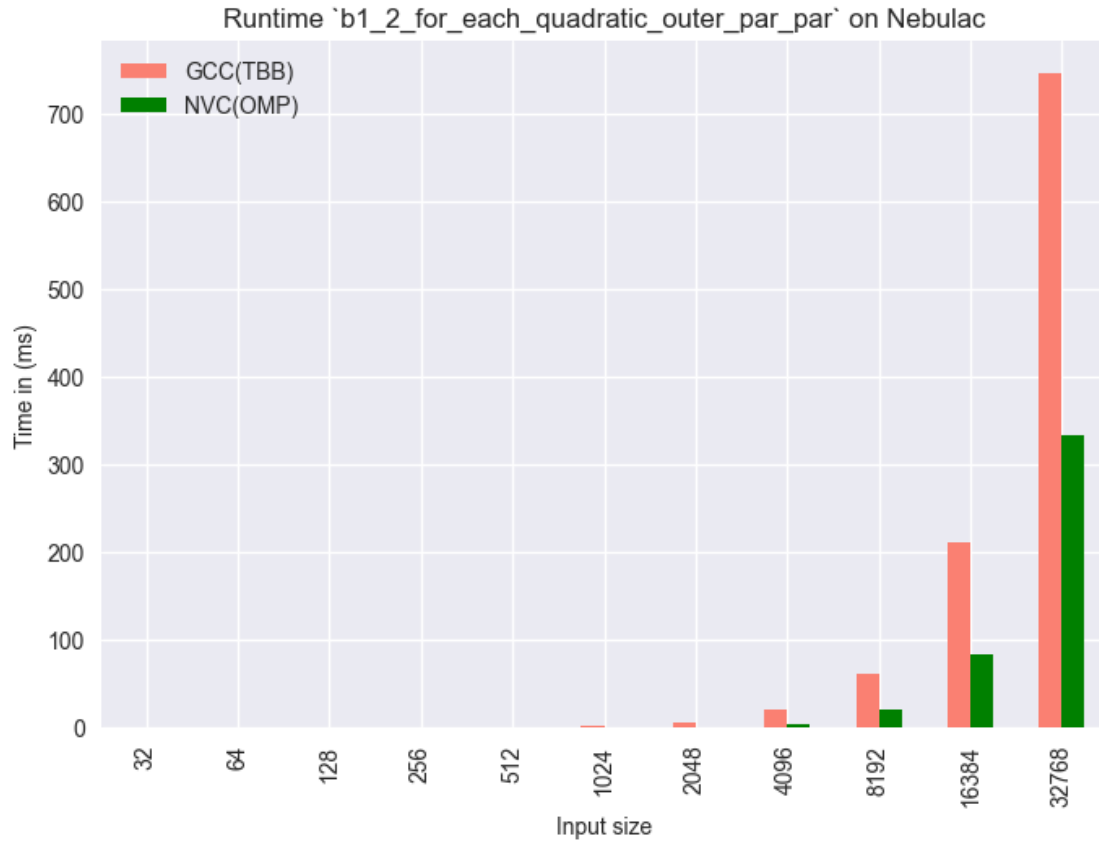
# convert time from ns to milliseconds because otherwise it will look really bad
b1_2_for_each_quadratic_par_par_time_merged['GCC(TBB)'] =
↳b1_2_for_each_quadratic_par_par_time_merged['GCC(TBB)'] / 1_000_000
b1_2_for_each_quadratic_par_par_time_merged['NVC(OMP)'] =
↳b1_2_for_each_quadratic_par_par_time_merged['NVC(OMP)'] / 1_000_000

# plot
b1_2_for_each_quadratic_par_par_time_merged.
↳plot(kind='bar', x='n', align='center', color=[GCC_TBB_COLOR, NVC_OMP_COLOR])

plt.ylabel('Time in (ms)')
plt.xlabel('Input size')
plt.title('Runtime `b1_2_for_each_quadratic_outer_par_par` on Nebulac')

plt.show()

```

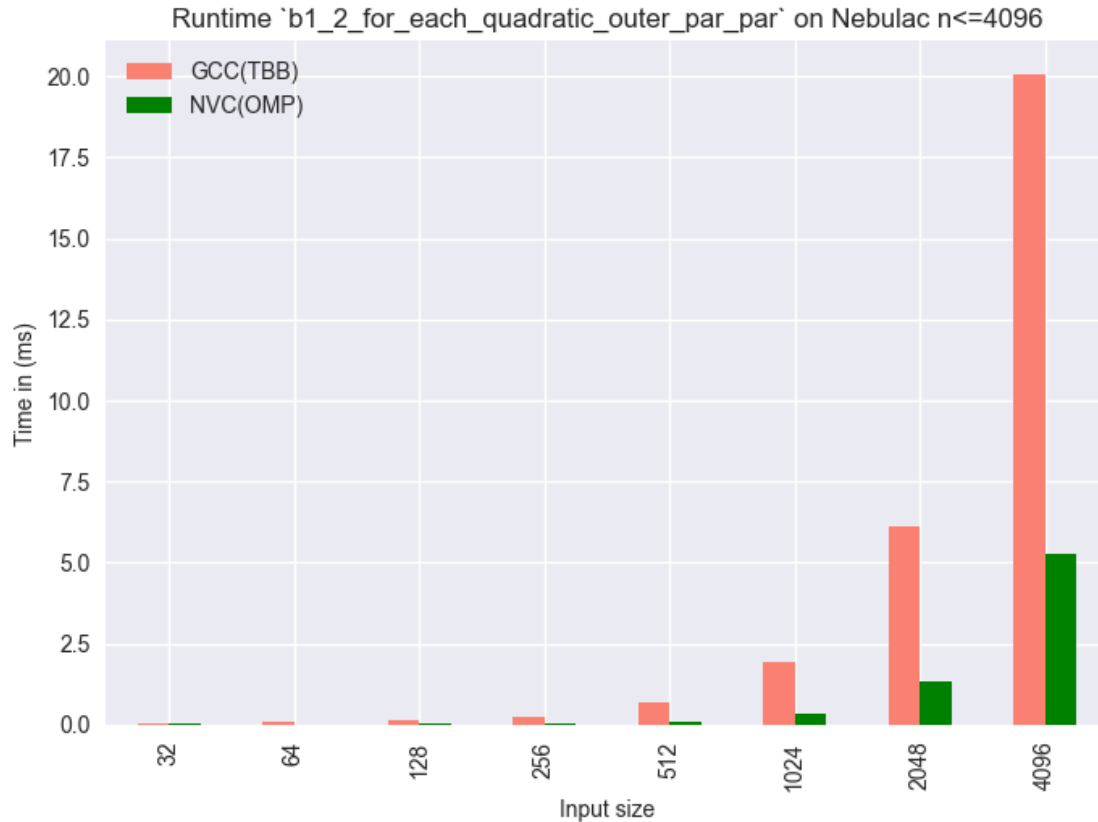
Adding a second graph because small numbers are not readable in the above graph

```
[14]: b1_2_for_each_quadratic_par_par_time_merged_sub_4096 =
↳ b1_2_for_each_quadratic_par_par_time_merged[b1_2_for_each_quadratic_par_par_time_merged['n'
↳ <= 4096]

# plot
b1_2_for_each_quadratic_par_par_time_merged_sub_4096.
↳ plot(kind='bar',x='n',align='center',color=[GCC_TBB_COLOR,NVC_OMP_COLOR])

plt.ylabel('Time in (ms)')
plt.xlabel('Input size')
plt.title('Runtime `b1_2_for_each_quadratic_outer_par_par` on Nebulac n<=4096')

plt.show()
```



Time Comparison - b1_4_for_each_exponential_par Check how the runtime without constraining the threads develops with increasing input size

```
[15]: # load data gcc (b1_4_for_each_exponential_par)
b1_4_for_each_exponential_par_gcc = extraction_pandas_frame_algo(root_dir + '/'
↳GCC_TBB/DEFAULT/b1_4_for_each_exponential_par__Default.csv',COMP="GCC(TBB)")

b1_4_for_each_exponential_par_gcc = b1_4_for_each_exponential_par_gcc.
↳drop(columns=['name', 'cpu_time', 'time_unit', 'median', 'stddev', 'Compiler'])
b1_4_for_each_exponential_par_gcc = b1_4_for_each_exponential_par_gcc.
↳rename(columns={'real_time': 'GCC(TBB)'})

# load data nvhpc (b1_4_for_each_exponential_par)
b1_4_for_each_exponential_par_nvc_omp = extraction_pandas_frame_algo(root_dir +
↳'/NVHPC_Multicore/DEFAULT/b1_4_for_each_exponential_par__Default.
↳csv',COMP="NVC(OMP)")

b1_4_for_each_exponential_par_nvc_omp = b1_4_for_each_exponential_par_nvc_omp.
↳drop(columns=['name', 'cpu_time', 'time_unit', 'median', 'stddev', 'Compiler'])
```

```

b1_4_for_each_exponential_par_nvc_omp = b1_4_for_each_exponential_par_nvc_omp.
↳rename(columns={'real_time': 'NVC(OMP)'})

# merge for plotting
b1_4_for_each_exponential_par_time_merged = pd.
↳merge(b1_4_for_each_exponential_par_gcc,↳
↳b1_4_for_each_exponential_par_nvc_omp, on='n')

# convert time from ns to milliseconds because otherwise it will look really bad
b1_4_for_each_exponential_par_time_merged['GCC(TBB)'] =↳
↳b1_4_for_each_exponential_par_time_merged['GCC(TBB)'] / 1_000_000
b1_4_for_each_exponential_par_time_merged['NVC(OMP)'] =↳
↳b1_4_for_each_exponential_par_time_merged['NVC(OMP)'] / 1_000_000

print(b1_4_for_each_exponential_par_time_merged)

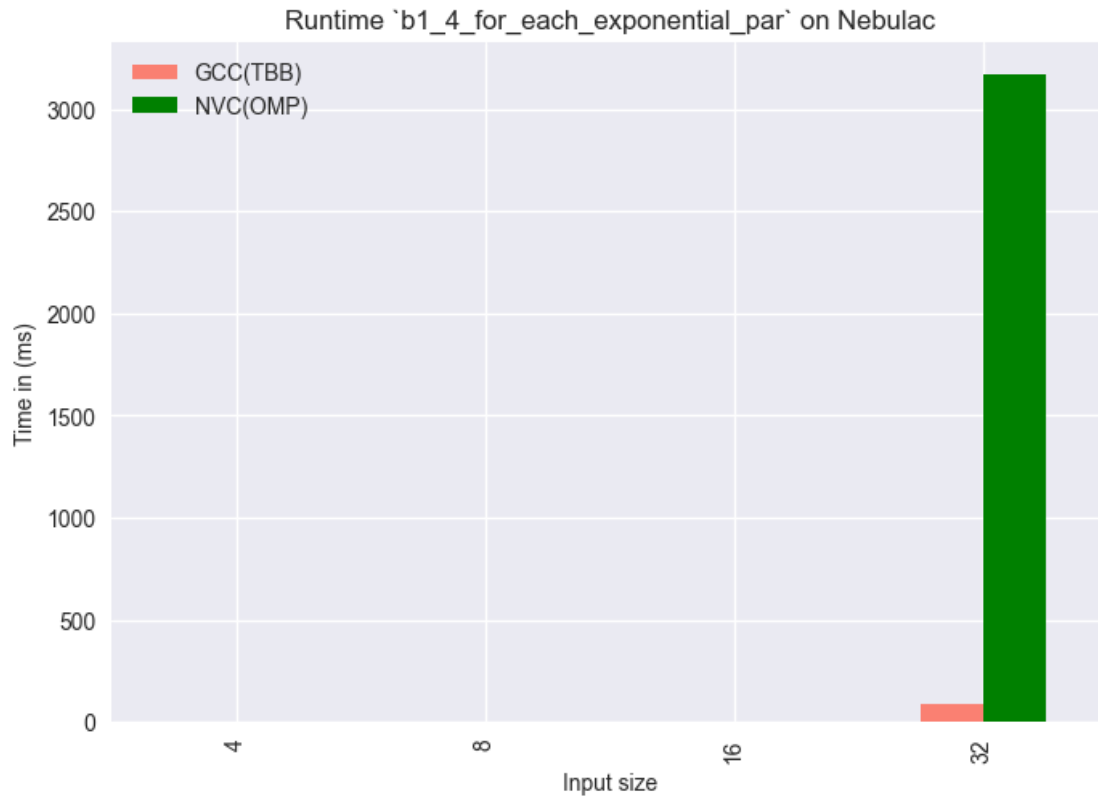
# plot
b1_4_for_each_exponential_par_time_merged.
↳plot(kind='bar',x='n',align='center',color=[GCC_TBB_COLOR,NVC_OMP_COLOR])

plt.ylabel('Time in (ms)')
plt.xlabel('Input size')
plt.title('Runtime `b1_4_for_each_exponential_par` on Nebulac')

plt.show()

```

	GCC(TBB)	n	NVC(OMP)
0	0.018690	4	0.012494
1	0.121331	8	0.042570
2	0.537180	16	1.722970
3	92.126600	32	3170.760000



Adding a second graph because small numbers are not readable in the above graph

```
[16]: b1_4_for_each_exponential_par_time_merged_sub_16 =
↳ b1_4_for_each_exponential_par_time_merged[b1_4_for_each_exponential_par_time_merged['n']]
↳ <= 16]

# convert from milliseconds to microseconds
b1_4_for_each_exponential_par_time_merged_sub_16['GCC(TBB)'] =
↳ b1_4_for_each_exponential_par_time_merged_sub_16['GCC(TBB)'] * 1_000
b1_4_for_each_exponential_par_time_merged_sub_16['NVC(OMP)'] =
↳ b1_4_for_each_exponential_par_time_merged_sub_16['NVC(OMP)'] * 1_000

# plot
b1_4_for_each_exponential_par_time_merged_sub_16.
↳ plot(kind='bar', x='n', align='center', color=[GCC_TBB_COLOR, NVC_OMP_COLOR])

print(b1_4_for_each_exponential_par_time_merged_sub_16)

plt.ylabel('Time in (µs)')
plt.xlabel('Input size')
```

```
plt.title('Runtime `b1_4_for_each_exponential_par` on Nebulac n<=16')
plt.show()
```

	GCC(TBB)	n	NVC(OMP)
0	18.6901	4	12.4941
1	121.3310	8	42.5701
2	537.1800	16	1722.9700

/var/folders/42/fk0jfryd1dd1ztdldncqc1cw0000gn/T/ipykernel_5746/1969448607.py:4:

SettingWithCopyWarning:

A value is trying to be set on a copy of a slice from a DataFrame.

Try using `.loc[row_indexer,col_indexer] = value` instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy

```
b1_4_for_each_exponential_par_time_merged_sub_16['GCC(TBB)'] =
b1_4_for_each_exponential_par_time_merged_sub_16['GCC(TBB)'] * 1_000
```

/var/folders/42/fk0jfryd1dd1ztdldncqc1cw0000gn/T/ipykernel_5746/1969448607.py:5:

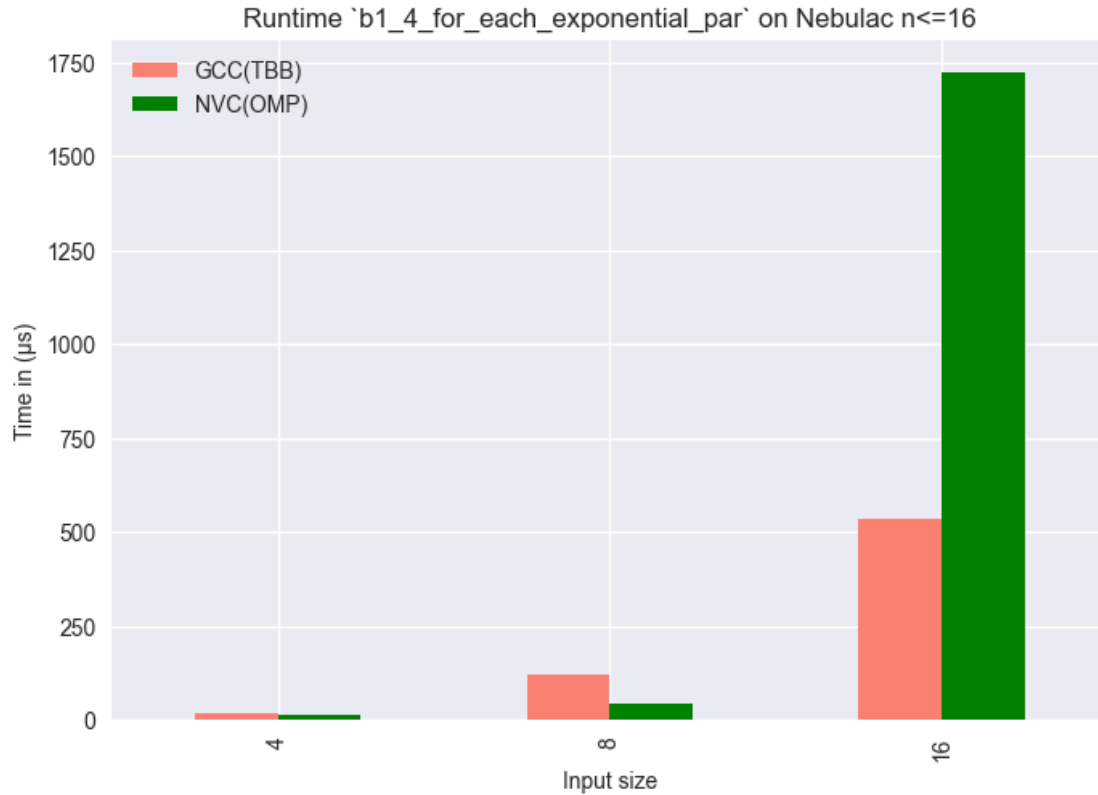
SettingWithCopyWarning:

A value is trying to be set on a copy of a slice from a DataFrame.

Try using `.loc[row_indexer,col_indexer] = value` instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy

```
b1_4_for_each_exponential_par_time_merged_sub_16['NVC(OMP)'] =
b1_4_for_each_exponential_par_time_merged_sub_16['NVC(OMP)'] * 1_000
```



2.1.2 Strong Scaling

$$S(p) = T(1) / T(p)$$

As based we use once the: * sequential algorithm * parallel algorithm (1 thread)

Strong Scaling - b1_1_for_each_linear 1 Million fixed input size with threads 1-64

Seq Base

```
[17]: # GCC
## load gcc (b1_1_for_each_linear_seq)
b1_1_for_each_linear_seq_gcc = extraction_pandas_frame_algo(root_dir + '/'
↳GCC_TBB/DEFAULT/b1_1_for_each_linear_seq_Default.csv',COMP="GCC(TBB)")

## load gcc threaded b1_1_for_each_linear_par
b1_1_for_each_linear_threads_gcc =↳
↳extraction_pandas_frame_algo_threaded(root_dir + '/GCC_TBB/
↳THREADS','b1_1_for_each_linear_par',[1,2,4,8,16,32,64],COMP="GCC(TBB)")

## calculate speedup
b1_1_for_each_linear_strong_scaling_seqbase_gcc =↳
↳calc_speedup_based_seq(b1_1_for_each_linear_seq_gcc,b1_1_for_each_linear_threads_gcc,"GCC(TBB)")
```

```

# NVC(OMP)
## load nvhpc (b1_1_for_each_linear_seq)
b1_1_for_each_linear_seq_nvc_omp = extraction_pandas_frame_algo(root_dir + '/'
↳NVHPC_Multicore/DEFAULT/b1_1_for_each_linear_seq_Default.
↳csv',COMP="NVC(OMP)")

## load nvhpc threaded b1_1_for_each_linear_par
b1_1_for_each_linear_threads_nvc_omp =↳
↳extraction_pandas_frame_algo_threaded(root_dir + '/NVHPC_Multicore/
↳THREADS', 'b1_1_for_each_linear_par', [1,2,4,8,16,32,64],COMP="NVC(OMP)")

## calculate speedup
b1_1_for_each_linear_strong_scaling_seqbase_nvc_omp =↳
↳calc_speedup_based_seq(b1_1_for_each_linear_seq_nvc_omp,b1_1_for_each_linear_threads_nvc_omp)

# merge for plotting
b1_1_for_each_linear_seq_speedup_merged = pd.
↳merge(b1_1_for_each_linear_strong_scaling_seqbase_gcc,↳
↳b1_1_for_each_linear_strong_scaling_seqbase_nvc_omp, on='threads')
print(b1_1_for_each_linear_seq_speedup_merged)

# plot strong scaling
ax = b1_1_for_each_linear_seq_speedup_merged.
↳plot(kind='bar',x='threads',align='center',color=[GCC_TBB_COLOR,NVC_OMP_COLOR])

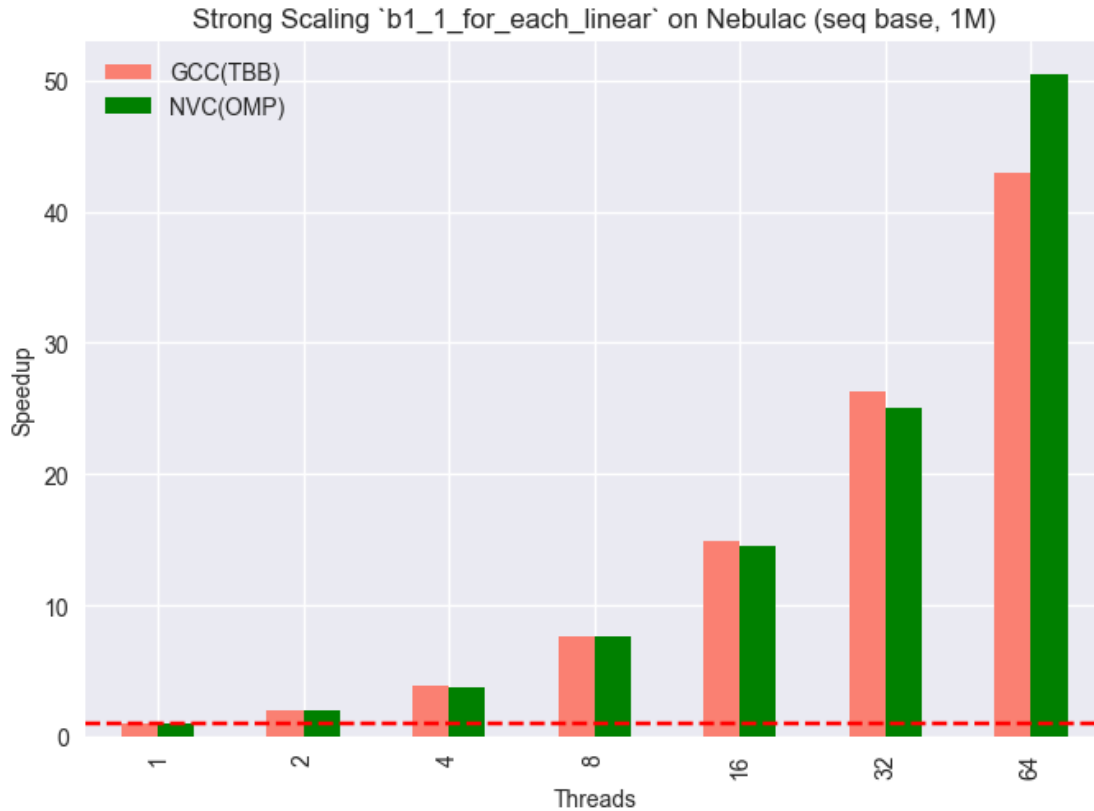
# adding horizontal line where there is speedup
ax.axhline(y=1, color='r', linestyle='--')

plt.ylabel('Speedup')
plt.xlabel('Threads')
plt.title('Strong Scaling `b1_1_for_each_linear` on Nebulac (seq base, 1M)')

plt.show()

```

	threads	GCC(TBB)	NVC(OMP)
0	1	0.997915	0.987061
1	2	1.993628	1.971258
2	4	3.966795	3.812405
3	8	7.715379	7.682825
4	16	14.945539	14.531737
5	32	26.258819	25.007096
6	64	42.943653	50.463093



```
[18]: ## efficiency graph
b1_1_for_each_linear_seq_efficiency = b1_1_for_each_linear_seq_speedup_merged.
    ↳copy()
b1_1_for_each_linear_seq_efficiency['GCC(TBB)'] =
    ↳b1_1_for_each_linear_seq_efficiency['GCC(TBB)'] /
    ↳b1_1_for_each_linear_seq_efficiency['threads']
b1_1_for_each_linear_seq_efficiency['NVC(OMP)'] =
    ↳b1_1_for_each_linear_seq_efficiency['NVC(OMP)'] /
    ↳b1_1_for_each_linear_seq_efficiency['threads']

print(b1_1_for_each_linear_seq_efficiency)

# plot efficiency
ax = b1_1_for_each_linear_seq_efficiency.
    ↳plot(x='threads',color=[GCC_TBB_COLOR,NVC_OMP_COLOR])

# adding horizontal line where there is speedup
ax.axhline(y=1, color='r', linestyle='--')

plt.ylim(0.4,1.05)
```



```

plt.xscale('log', base=2)
current_values = plt.gca().get_xticks()
plt.gca().set_xticklabels(['{:,.0f}'.format(x) for x in current_values])

plt.ylabel('Efficiency')
plt.xlabel('Threads')
plt.title('Efficiency `b1_1_for_each_linear` on Nebulac (seq base, 1M)')

plt.show()

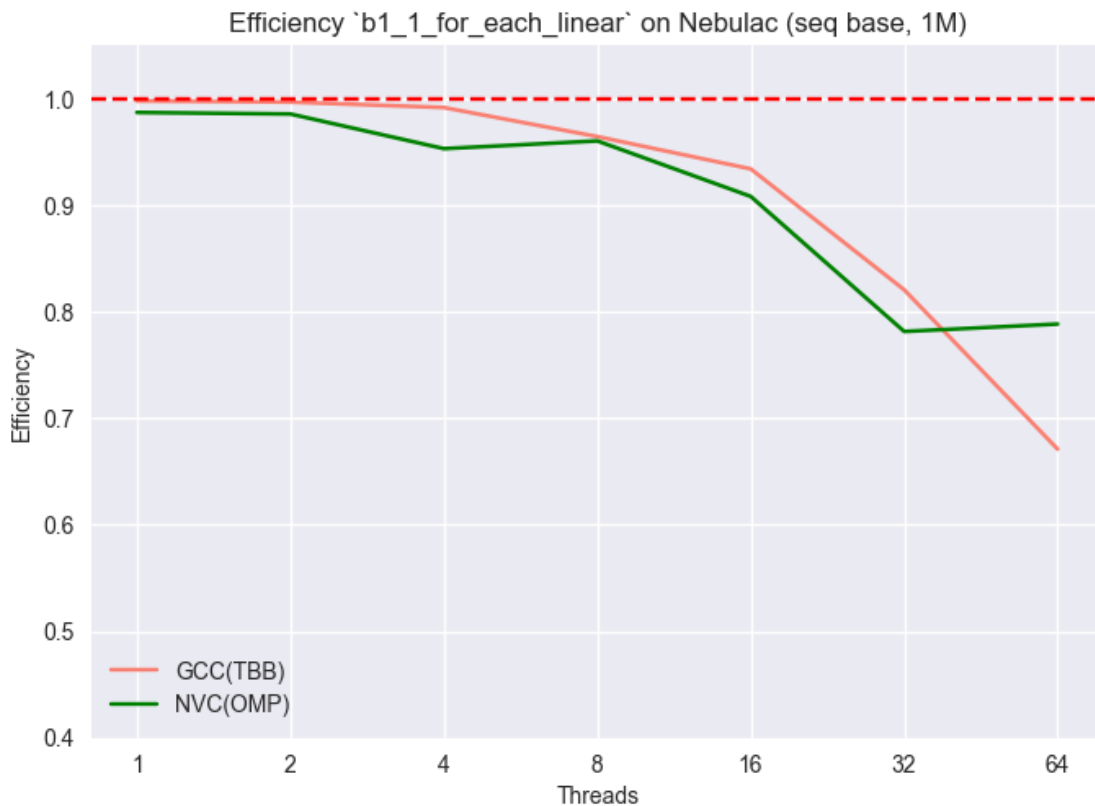
```

```

/var/folders/42/fk0jfryd1dd1ztdldncqc1cw0000gn/T/ipykernel_5746/3790263233.py:18
: UserWarning: FixedFormatter should only be used together with FixedLocator
  plt.gca().set_xticklabels(['{:,.0f}'.format(x) for x in current_values])

```

	threads	GCC(TBB)	NVC(OMP)
0	1	0.997915	0.987061
1	2	0.996814	0.985629
2	4	0.991699	0.953101
3	8	0.964422	0.960353
4	16	0.934096	0.908234
5	32	0.820588	0.781472
6	64	0.670995	0.788486



Par(1) Base

```
[19]: # GCC(TBB)
## load gcc threaded b1_1_for_each_linear_par
b1_1_for_each_linear_threads_gcc = □
↳extraction_pandas_frame_algo_threaded(root_dir + '/GCC_TBB/
↳THREADS', 'b1_1_for_each_linear_par', [1,2,4,8,16,32,64], COMP="GCC(TBB)")

## calc strong scaling
b1_1_for_each_linear_strong_scaling_parbase_gcc = □
↳calc_speedup_based_par(b1_1_for_each_linear_threads_gcc, "GCC(TBB)")

# NVC(OMP)
## load nvhpc threaded b1_1_for_each_linear_par
b1_1_for_each_linear_threads_nvc_omp = □
↳extraction_pandas_frame_algo_threaded(root_dir + '/NVHPC_Multicore/
↳THREADS', 'b1_1_for_each_linear_par', [1,2,4,8,16,32,64], COMP="NVC(OMP)")

## calc strong scaling
b1_1_for_each_linear_strong_scaling_parbase_nvc_omp = □
↳calc_speedup_based_par(b1_1_for_each_linear_threads_nvc_omp, "NVC(OMP)")

# merge for plotting
b1_1_for_each_linear_seq_parbase_speedup_merged = pd.
↳merge(b1_1_for_each_linear_strong_scaling_parbase_gcc, □
↳b1_1_for_each_linear_strong_scaling_parbase_nvc_omp, on='threads')
print(b1_1_for_each_linear_seq_parbase_speedup_merged)

# plot strong scaling
ax = b1_1_for_each_linear_seq_parbase_speedup_merged.
↳plot(kind='bar', x='threads', align='center', color=[GCC_TBB_COLOR, NVC_OMP_COLOR])

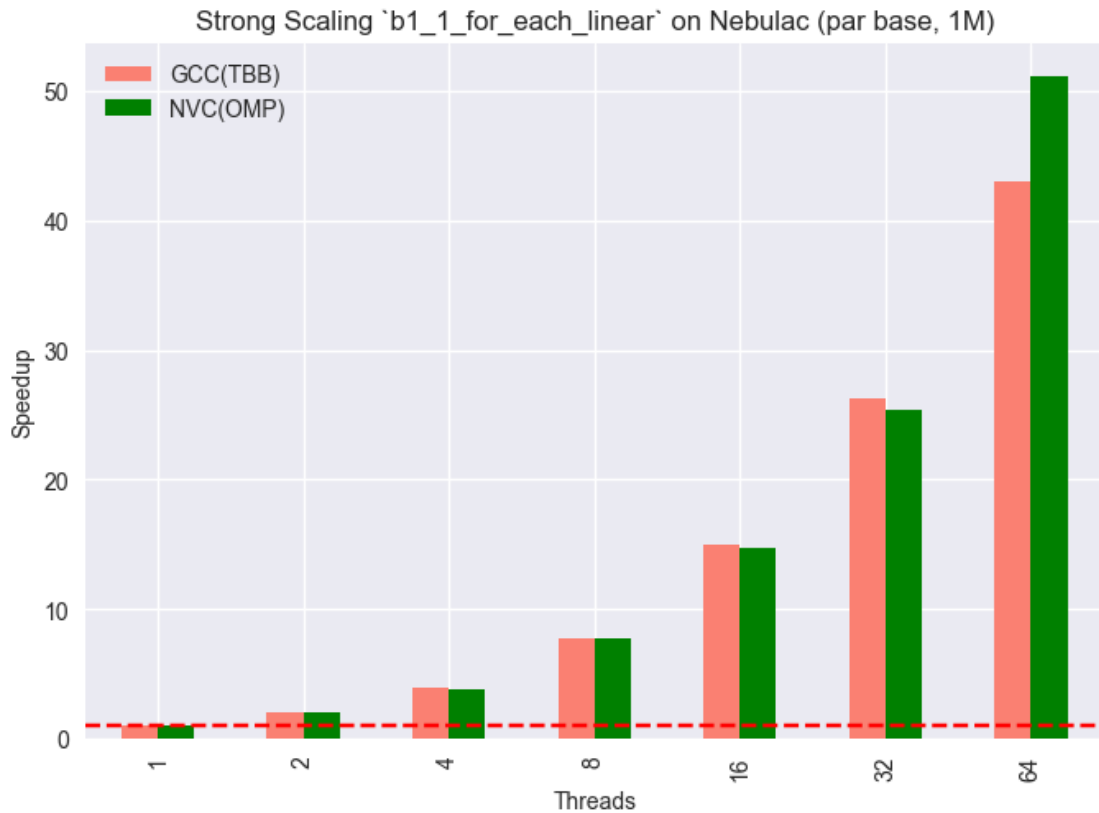
# adding horizontal line where there is speedup
ax.axhline(y=1, color='r', linestyle='--')

plt.ylabel('Speedup')
plt.xlabel('Threads')
plt.title('Strong Scaling `b1_1_for_each_linear` on Nebulac (par base, 1M)')

plt.show()
```

	threads	GCC(TBB)	NVC(OMP)
0	1	1.000000	1.000000
1	2	1.997794	1.997099

2	4	3.975084	3.862382
3	8	7.731503	7.783538
4	16	14.976772	14.722232
5	32	26.313694	25.334912
6	64	43.033396	51.124609



```
[20]: ## efficiency graph
b1_1_for_each_linear_seq_efficiency =
    ↳ b1_1_for_each_linear_seq_parbase_speedup_merged.copy()
b1_1_for_each_linear_seq_efficiency['GCC(TBB)'] =
    ↳ b1_1_for_each_linear_seq_efficiency['GCC(TBB)'] /
    ↳ b1_1_for_each_linear_seq_efficiency['threads']
b1_1_for_each_linear_seq_efficiency['NVC(OMP)'] =
    ↳ b1_1_for_each_linear_seq_efficiency['NVC(OMP)'] /
    ↳ b1_1_for_each_linear_seq_efficiency['threads']

print(b1_1_for_each_linear_seq_efficiency)

# plot efficiency
ax = b1_1_for_each_linear_seq_efficiency.
    ↳ plot(x='threads', color=[GCC_TBB_COLOR, NVC_OMP_COLOR])
```

```

# adding horizontal line where there is speedup
ax.axhline(y=1, color='r', linestyle='--')

plt.ylim(0.4,1.05)

plt.xscale('log', base=2)
current_values = plt.gca().get_xticks()
plt.gca().set_xticklabels(['{:, .0f}'.format(x) for x in current_values])

plt.ylabel('Efficiency')
plt.xlabel('Threads')
plt.title('Efficiency `b1_1_for_each_linear` on Nebulac (par base, 1M)')

plt.show()

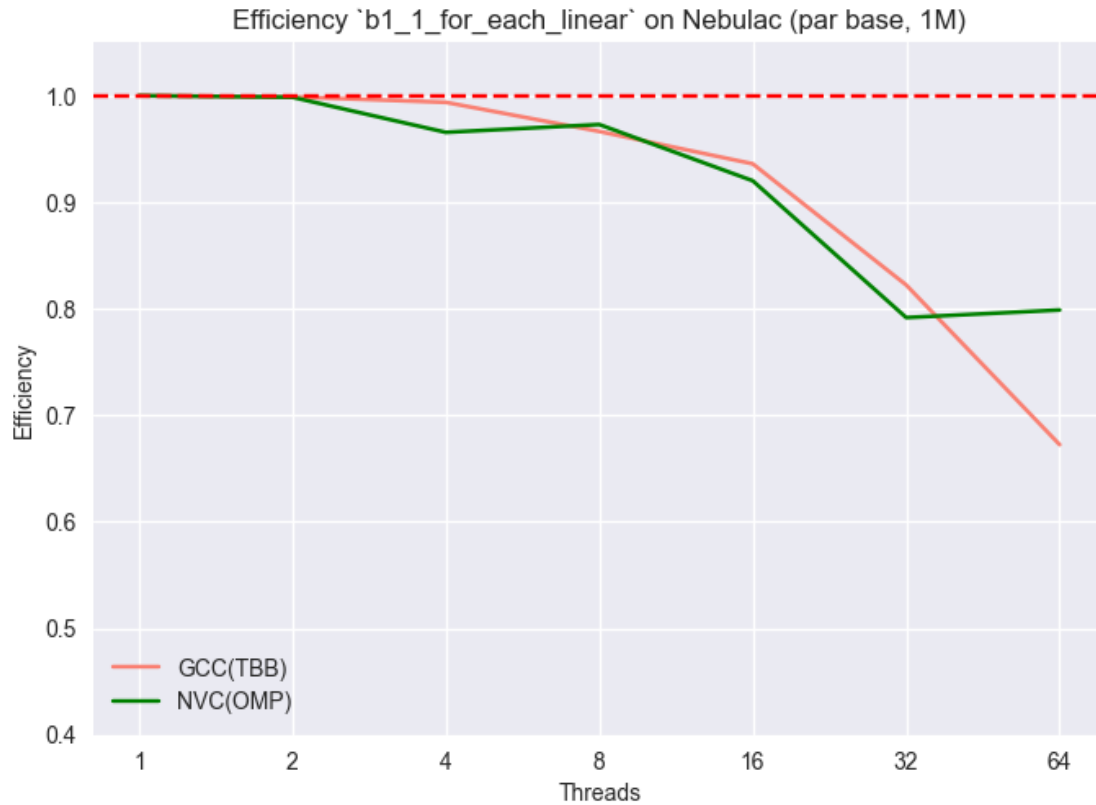
```

	threads	GCC(TBB)	NVC(OMP)
0	1	1.000000	1.000000
1	2	0.998897	0.998549
2	4	0.993771	0.965595
3	8	0.966438	0.972942
4	16	0.936048	0.920140
5	32	0.822303	0.791716
6	64	0.672397	0.798822

```

/var/folders/42/fk0jfryd1dd1ztdldncqc1cw0000gn/T/ipykernel_5746/3088997708.py:18
: UserWarning: FixedFormatter should only be used together with FixedLocator
plt.gca().set_xticklabels(['{:, .0f}'.format(x) for x in current_values])

```



Strong Scaling - b1_2_for_each_quadratic 1 Million fixed input size with threads 1-64

Seq Base Here we wont do it with seq base because its not really realistic

Par(1) Base

```
[21]: # GCC(TBB)
## load gcc threaded b1_2_for_each_quadratic_outer_std::execution::
    ↪parallel_policy_par
b1_2_for_each_quadratic_par_par_threads_gcc = □
    ↪extraction_pandas_frame_algo_threaded(root_dir + '/GCC_TBB/
    ↪THREADS','b1_2_for_each_quadratic_outer_std::execution::
    ↪parallel_policy_par',[1,2,4,8,16,32,64],COMP="GCC(TBB)",input_size=32768)

## calc strong scaling
b1_2_for_each_quadratic_par_par_scaling_parbase_gcc = □
    ↪calc_speedup_based_par(b1_2_for_each_quadratic_par_par_threads_gcc,"GCC(TBB)")

# NVC(OMP)
## load nvhpc threaded b1_2_for_each_quadratic_outer_std::execution::
    ↪parallel_policy_par
```

```

b1_2_for_each_quadratic_par_par_threads_nvc_omp =
↳extraction_pandas_frame_algo_threaded(root_dir + '/NVHPC_Multicore/
↳THREADS', 'b1_2_for_each_quadratic_outer_std::execution::
↳parallel_policy_par', [1,2,4,8,16,32,64], COMP="NVC(OMP)", input_size=32768)

## calc strong scaling
b1_2_for_each_quadratic_par_par_scaling_parbase_nvc_omp =
↳calc_speedup_based_par(b1_2_for_each_quadratic_par_par_threads_nvc_omp, "NVC(OMP)")

# merge for plotting
b1_2_for_each_quadratic_par_par_speedup_merged = pd.
↳merge(b1_2_for_each_quadratic_par_par_scaling_parbase_gcc,
↳b1_2_for_each_quadratic_par_par_scaling_parbase_nvc_omp, on='threads')
print(b1_2_for_each_quadratic_par_par_speedup_merged)

# plot strong scaling
ax = b1_2_for_each_quadratic_par_par_speedup_merged.
↳plot(kind='bar', x='threads', align='center', color=[GCC_TBB_COLOR, NVC_OMP_COLOR])

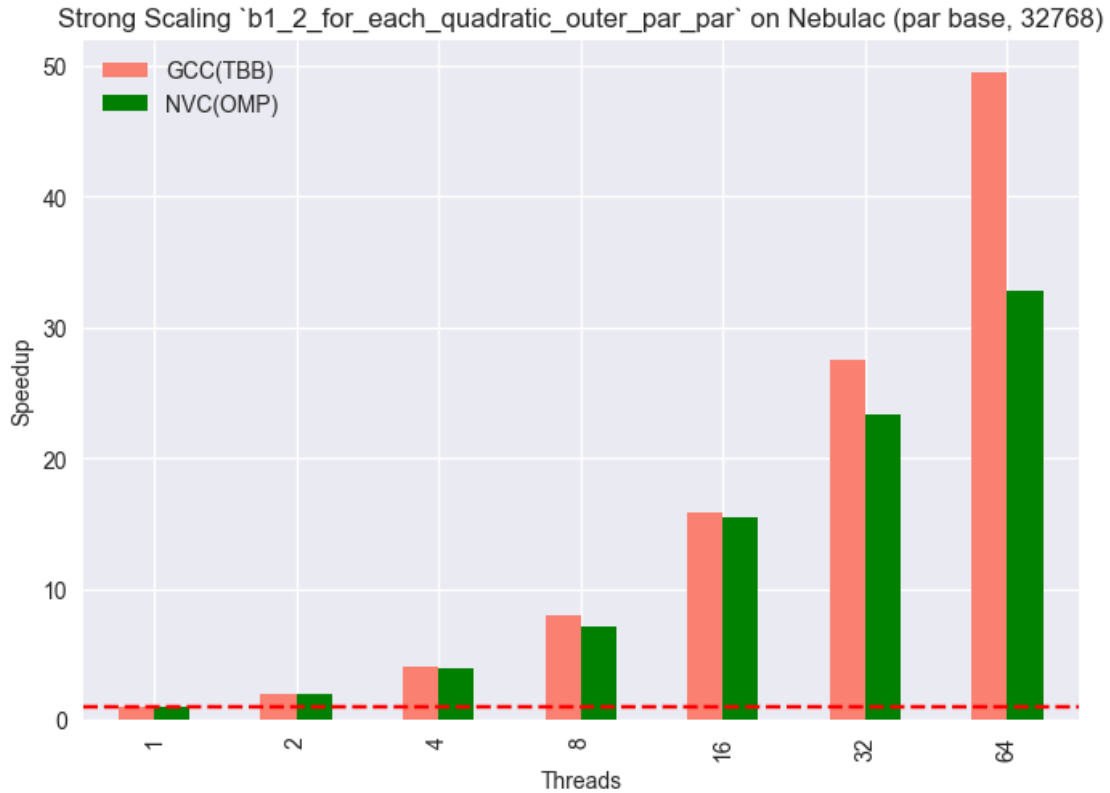
# adding horizontal line where there is speedup
ax.axhline(y=1, color='r', linestyle='--')

plt.ylabel('Speedup')
plt.xlabel('Threads')
plt.title('Strong Scaling `b1_2_for_each_quadratic_outer_par_par` on Nebulac
↳(par base, 32768)')

plt.show()

```

	threads	GCC(TBB)	NVC(OMP)
0	1	1.000000	1.000000
1	2	2.012084	1.989333
2	4	4.028875	3.965606
3	8	8.029452	7.085557
4	16	15.840287	15.510771
5	32	27.573592	23.361771
6	64	49.508283	32.807058



```
[22]: ## efficiency graph
b1_2_for_each_quadratic_par_par_efficiency = 
    ↳ b1_2_for_each_quadratic_par_par_speedup_merged.copy()
b1_2_for_each_quadratic_par_par_efficiency['GCC(TBB)'] = 
    ↳ b1_2_for_each_quadratic_par_par_efficiency['GCC(TBB)'] / 
    ↳ b1_2_for_each_quadratic_par_par_efficiency['threads']
b1_2_for_each_quadratic_par_par_efficiency['NVC(OMP)'] = 
    ↳ b1_2_for_each_quadratic_par_par_efficiency['NVC(OMP)'] / 
    ↳ b1_2_for_each_quadratic_par_par_efficiency['threads']

print(b1_2_for_each_quadratic_par_par_efficiency)

# plot efficiency
ax = b1_2_for_each_quadratic_par_par_efficiency.
    ↳ plot(x='threads', color=[GCC_TBB_COLOR, NVC_OMP_COLOR])

# adding horizontal line where there is speedup
ax.axhline(y=1, color='r', linestyle='--')

plt.ylim(0.4, 1.05)
```

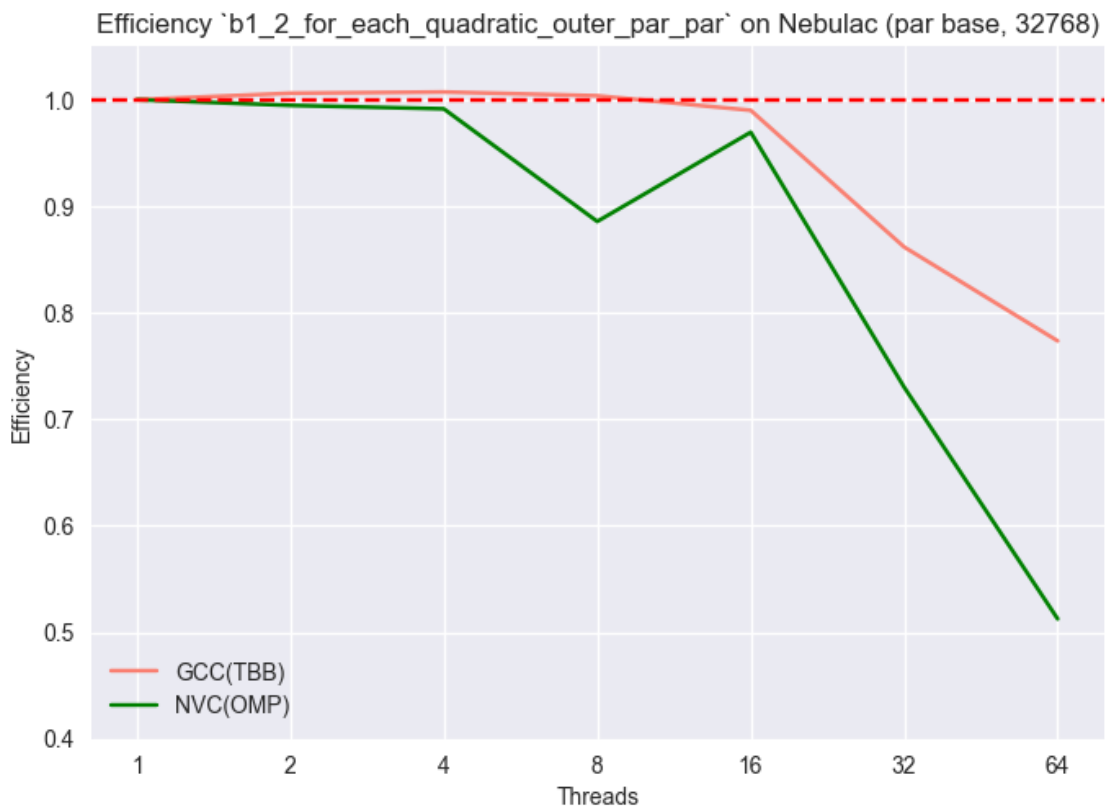
```
plt.xscale('log', base=2)
current_values = plt.gca().get_xticks()
plt.gca().set_xticklabels(['{:,.0f}'.format(x) for x in current_values])

plt.ylabel('Efficiency')
plt.xlabel('Threads')
plt.title('Efficiency `b1_2_for_each_quadratic_outer_par_par` on Nebulac (par_
↳base, 32768)')

plt.show()
```

	threads	GCC(TBB)	NVC(OMP)
0	1	1.000000	1.000000
1	2	1.006042	0.994667
2	4	1.007219	0.991402
3	8	1.003681	0.885695
4	16	0.990018	0.969423
5	32	0.861675	0.730055
6	64	0.773567	0.512610

/var/folders/42/fk0jfryd1dd1ztdldncqc1cw0000gn/T/ipykernel_5746/328153834.py:18:
UserWarning: FixedFormatter should only be used together with FixedLocator
plt.gca().set_xticklabels(['{:,.0f}'.format(x) for x in current_values])



Strong Scaling - b1_4_for_each_exponential 32 fixed input size with threads 1-64

Seq Base

[23]:

```
# GCC
## load gcc (b1_4_for_each_exponential_seq)
b1_4_for_each_exponential_seq_gcc = extraction_pandas_frame_algo(root_dir + '/'
    ↪GCC_TBB/DEFAULT/b1_4_for_each_exponential_seq_Default.csv', COMP="GCC(TBB)")

## load gcc threaded b1_4_for_each_exponential_par
b1_4_for_each_exponential_threads_gcc =
    ↪extraction_pandas_frame_algo_threaded(root_dir + '/GCC_TBB/
    ↪THREADS', 'b1_4_for_each_exponential_par', [1,2,4,8,16,32,64], COMP="GCC(TBB)", input_size=32)

## calculate speedup
b1_4_for_each_exponential_strong_scaling_seqbase_gcc =
    ↪calc_speedup_based_seq(b1_4_for_each_exponential_seq_gcc, b1_4_for_each_exponential_threads_gcc)

# NVC(OMP)
## load nvhpc (b1_4_for_each_exponential_seq)
b1_4_for_each_exponential_seq_nvc_omp = extraction_pandas_frame_algo(root_dir +
    ↪'/NVHPC_Multicore/DEFAULT/b1_4_for_each_exponential_seq_Default.
    ↪csv', COMP="NVC(OMP)")

## load nvhpc threaded b1_4_for_each_exponential_par
b1_4_for_each_exponential_threads_nvc_omp =
    ↪extraction_pandas_frame_algo_threaded(root_dir + '/NVHPC_Multicore/
    ↪THREADS', 'b1_4_for_each_exponential_par', [1,2,4,8,16,32,64], COMP="NVC(OMP)", input_size=32)

## calculate speedup
b1_4_for_each_exponential_strong_scaling_seqbase_nvc_omp =
    ↪calc_speedup_based_seq(b1_4_for_each_exponential_seq_nvc_omp, b1_4_for_each_exponential_threads_nvc_omp)

# merge for plotting
b1_4_for_each_exponential_seq_speedup_merged = pd.
    ↪merge(b1_4_for_each_exponential_strong_scaling_seqbase_gcc,
    ↪b1_4_for_each_exponential_strong_scaling_seqbase_nvc_omp, on='threads')
print(b1_4_for_each_exponential_seq_speedup_merged)

# plot strong scaling
ax = b1_4_for_each_exponential_seq_speedup_merged.
    ↪plot(kind='bar', x='threads', align='center', color=[GCC_TBB_COLOR, NVC_OMP_COLOR])

# adding horizontal line where there is speedup
```

```

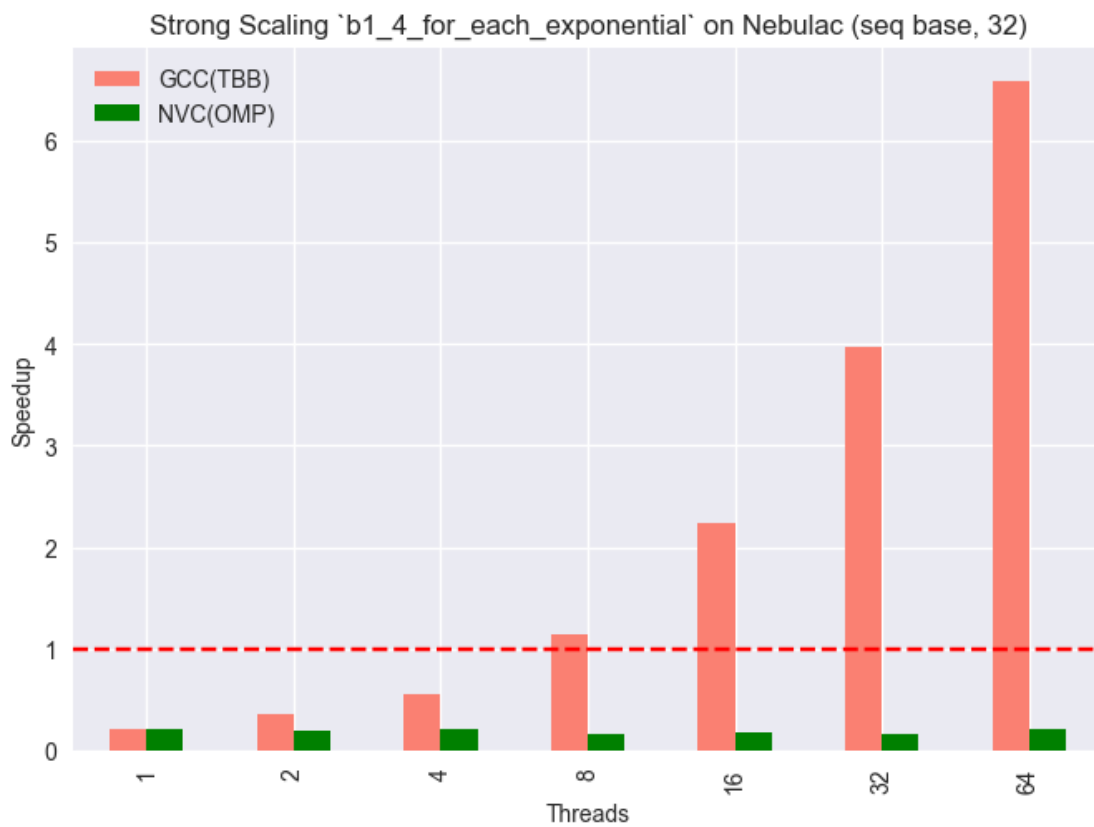
ax.axhline(y=1, color='r', linestyle='--')

plt.ylabel('Speedup')
plt.xlabel('Threads')
plt.title('Strong Scaling `b1_4_for_each_exponential` on Nebulac (seq base, 32)')

plt.show()

```

	threads	GCC(TBB)	NVC(OMP)
0	1	0.220355	0.210447
1	2	0.362259	0.195431
2	4	0.566315	0.223379
3	8	1.145408	0.173250
4	16	2.241314	0.190904
5	32	3.970097	0.171405
6	64	6.585767	0.217449



```
[24]: ## efficiency graph
b1_4_for_each_exponential_seq_efficiency =  $\square$ 
     $\hookrightarrow$  b1_4_for_each_exponential_seq_speedup_merged.copy()
b1_4_for_each_exponential_seq_efficiency['GCC(TBB)'] =  $\square$ 
     $\hookrightarrow$  b1_4_for_each_exponential_seq_efficiency['GCC(TBB)'] /  $\square$ 
     $\hookrightarrow$  b1_4_for_each_exponential_seq_efficiency['threads']
b1_4_for_each_exponential_seq_efficiency['NVC(OMP)'] =  $\square$ 
     $\hookrightarrow$  b1_4_for_each_exponential_seq_efficiency['NVC(OMP)'] /  $\square$ 
     $\hookrightarrow$  b1_4_for_each_exponential_seq_efficiency['threads']

print(b1_4_for_each_exponential_seq_efficiency)

# plot efficiency
ax = b1_4_for_each_exponential_seq_efficiency.
     $\hookrightarrow$  plot(x='threads', color=[GCC_TBB_COLOR, NVC_OMP_COLOR])

# adding horizontal line where there is speedup
ax.axhline(y=1, color='r', linestyle='--')

plt.ylim(0,1.05)

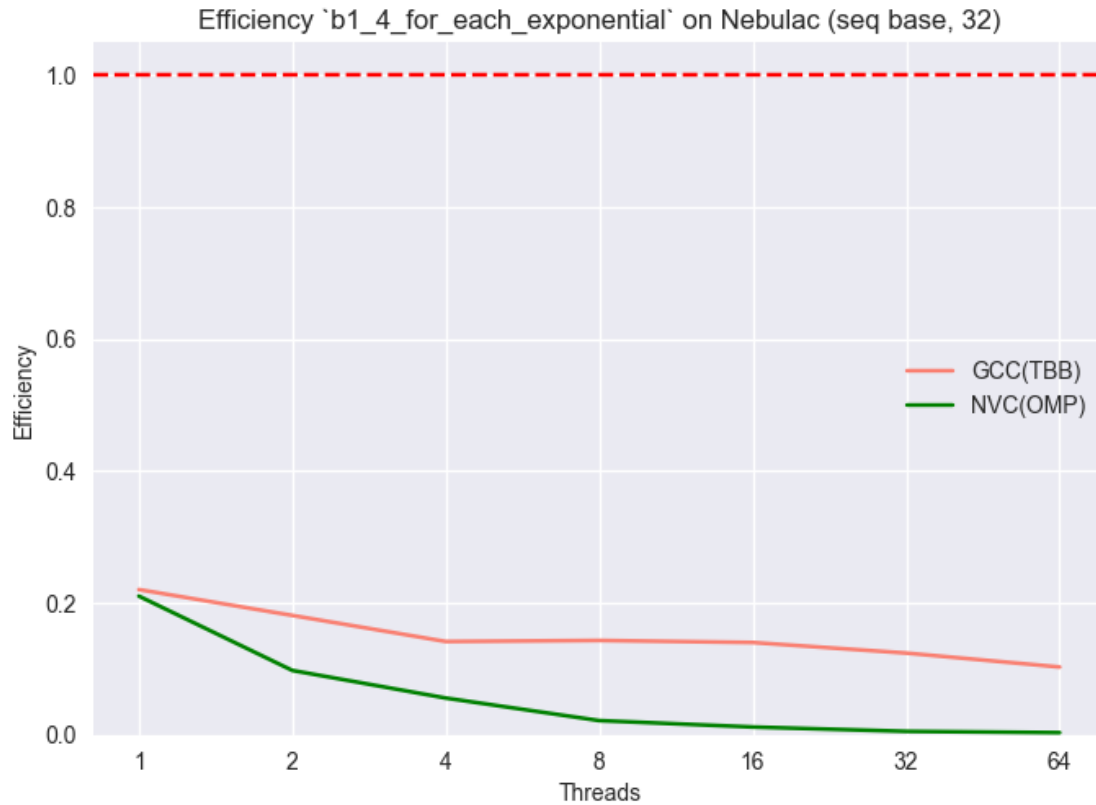
plt.xscale('log', base=2)
current_values = plt.gca().get_xticks()
plt.gca().set_xticklabels(['{:, .0f}'.format(x) for x in current_values])

plt.ylabel('Efficiency')
plt.xlabel('Threads')
plt.title('Efficiency `b1_4_for_each_exponential` on Nebulac (seq base, 32)')

plt.show()
```

	threads	GCC(TBB)	NVC(OMP)
0	1	0.220355	0.210447
1	2	0.181129	0.097715
2	4	0.141579	0.055845
3	8	0.143176	0.021656
4	16	0.140082	0.011931
5	32	0.124066	0.005356
6	64	0.102903	0.003398

```
/var/folders/42/fk0jfryd1dd1ztdldncqc1cw0000gn/T/ipykernel_5746/4127874945.py:18
: UserWarning: FixedFormatter should only be used together with FixedLocator
  plt.gca().set_xticklabels(['{:, .0f}'.format(x) for x in current_values])
```



Par(1) Base

```
[25]: # GCC
## load gcc threaded b1_4_for_each_exponential_par
b1_4_for_each_exponential_threads_gcc =
↳extraction_pandas_frame_algo_threaded(root_dir + '/GCC_TBB/
↳THREADS', 'b1_4_for_each_exponential_par', [1,2,4,8,16,32,64], COMP="GCC(TBB)", input_size=32)

## calc strong scaling
b1_4_for_each_exponential_strong_scaling_parbase_gcc =
↳calc_speedup_based_par(b1_4_for_each_exponential_threads_gcc, "GCC(TBB)")

# NVC(OMP)
## load nvhpc threaded b1_4_for_each_exponential_par
b1_4_for_each_exponential_threads_nvc_omp =
↳extraction_pandas_frame_algo_threaded(root_dir + '/NVHPC_Multicore/
↳THREADS', 'b1_4_for_each_exponential_par', [1,2,4,8,16,32,64], COMP="NVC(OMP)", input_size=32)

## calc strong scaling
```

```

b1_4_for_each_exponential_strong_scaling_parbase_nvc_omp = ␣
    ↪ calc_speedup_based_par(b1_4_for_each_exponential_threads_nvc_omp, "NVC(OMP)")

# merge for plotting
b1_4_for_each_linear_seq_parbase_speedup_merged = pd.
    ↪ merge(b1_4_for_each_exponential_strong_scaling_parbase_gcc, ␣
    ↪ b1_4_for_each_exponential_strong_scaling_parbase_nvc_omp, on='threads')
print(b1_4_for_each_linear_seq_parbase_speedup_merged)

# plot strong scaling
ax = b1_4_for_each_linear_seq_parbase_speedup_merged.
    ↪ plot(kind='bar', x='threads', align='center', color=[GCC_TBB_COLOR, NVC_OMP_COLOR])

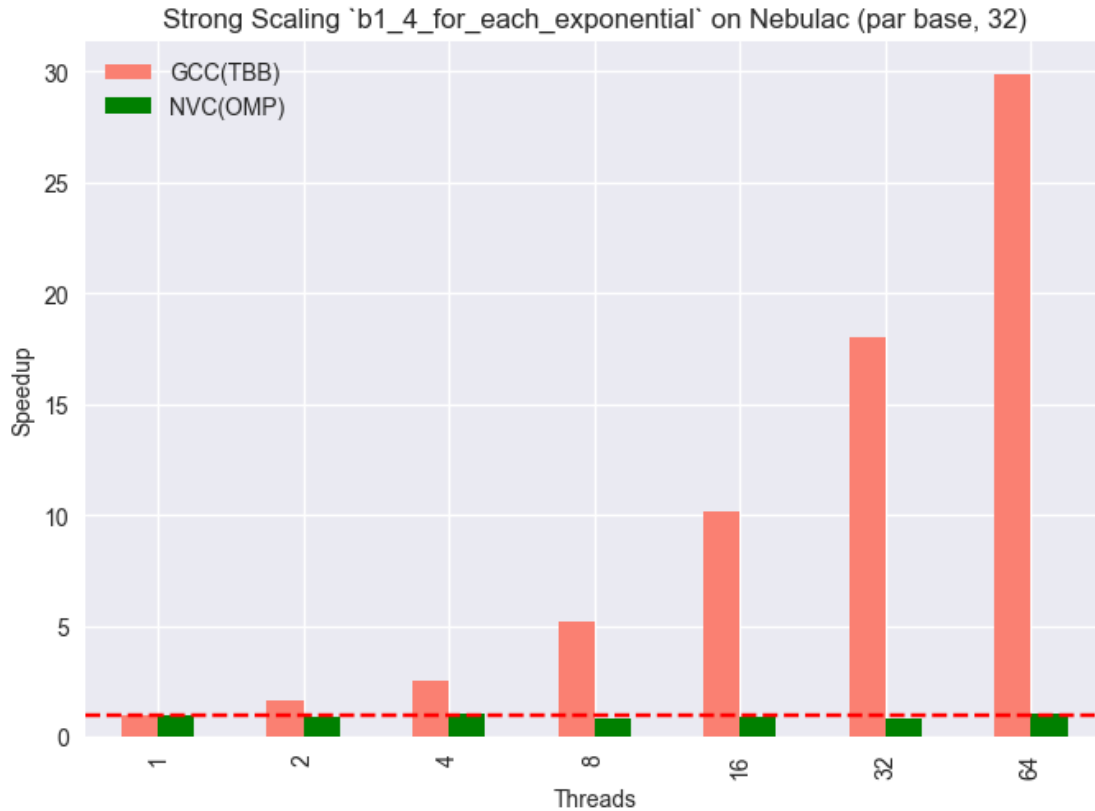
# adding horizontal line where there is speedup
ax.axhline(y=1, color='r', linestyle='--')

plt.ylabel('Speedup')
plt.xlabel('Threads')
plt.title('Strong Scaling `b1_4_for_each_exponential` on Nebulac (par base, ␣
    ↪ 32)')

plt.show()

```

	threads	GCC(TBB)	NVC(OMP)
0	1	1.000000	1.000000
1	2	1.643982	0.928644
2	4	2.570017	1.061446
3	8	5.198022	0.823248
4	16	10.171399	0.907134
5	32	18.016857	0.814478
6	64	29.887137	1.033271



```
[26]: ## efficiency graph
b1_4_for_each_linear_seq_parbase_efficiency = _
↳ b1_4_for_each_linear_seq_parbase_speedup_merged.copy()
b1_4_for_each_linear_seq_parbase_efficiency['GCC(TBB)'] = _
↳ b1_4_for_each_linear_seq_parbase_efficiency['GCC(TBB)'] / _
↳ b1_4_for_each_linear_seq_parbase_efficiency['threads']
b1_4_for_each_linear_seq_parbase_efficiency['NVC(OMP)'] = _
↳ b1_4_for_each_linear_seq_parbase_efficiency['NVC(OMP)'] / _
↳ b1_4_for_each_linear_seq_parbase_efficiency['threads']

print(b1_4_for_each_linear_seq_parbase_efficiency)

# plot efficiency
ax = b1_4_for_each_linear_seq_parbase_efficiency.
↳ plot(x='threads', color=[GCC_TBB_COLOR, NVC_OMP_COLOR])

# adding horizontal line where there is speedup
ax.axhline(y=1, color='r', linestyle='--')

plt.ylim(0, 1.05)
```

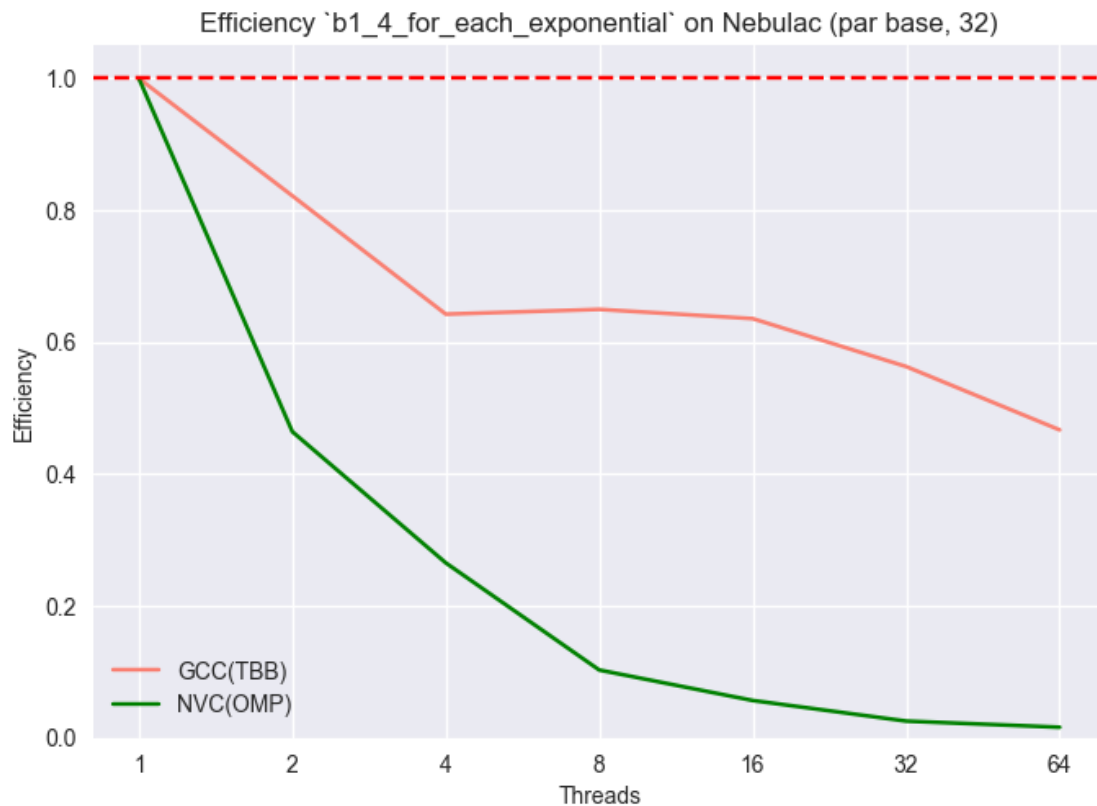
```
plt.xscale('log', base=2)
current_values = plt.gca().get_xticks()
plt.gca().set_xticklabels(['{:,.0f}'.format(x) for x in current_values])

plt.ylabel('Efficiency')
plt.xlabel('Threads')
plt.title('Efficiency `b1_4_for_each_exponential` on Nebulac (par base, 32)')

plt.show()
```

	threads	GCC(TBB)	NVC(OMP)
0	1	1.000000	1.000000
1	2	0.821991	0.464322
2	4	0.642504	0.265362
3	8	0.649753	0.102906
4	16	0.635712	0.056696
5	32	0.563027	0.025452
6	64	0.466987	0.016145

/var/folders/42/fk0jfryd1dd1ztdldncqc1cw0000gn/T/ipykernel_5746/2443303117.py:18
: UserWarning: FixedFormatter should only be used together with FixedLocator
plt.gca().set_xticklabels(['{:,.0f}'.format(x) for x in current_values])



2.1.3 Performance Portability Calculation (Inter Compiler)

for this group we can “calculate” a performance probability by looking at the strong scaling speedup every compiler has when using the max amount of cores. (aka running with 1M entries at max core) (inspired by [1])

example:

	achieved	perfect	efficiency
-----	-----	-----	-----
GCC(TBB)	12	16	12/16=0.75
NVC(OMP)	16	16	16/16=1
NVC(GPU)	0	0	0
Intel	14	16	14/16=0.875

Performance Portability for `{GCC(TBB), NVC(OMP), NVC(GPU), Intel}` = 0

Performance Portability for `{GCC(TBB), NVC(OMP), Intel}` = $\frac{3}{((1/0.75) + (1/1) + (1/0.875))}$

```
[27]: max_cores :int = 64

b1_1_data = []
b1_2_data = []
b1_4_data = []

print("GCC")
# calculate efficiency for gcc on max core for `b1_1_for_each_linear`
b1_1_for_each_linear_speed_up_64_gcc = □
    ↳ b1_1_for_each_linear_strong_scaling_parbase_gcc[b1_1_for_each_linear_strong_scaling_parbase
    ↳ == 64].iloc[0]['GCC(TBB)']
b1_1_data.append(b1_1_for_each_linear_speed_up_64_gcc)

print("\tb1_1 Speedup(64):", b1_1_for_each_linear_speed_up_64_gcc)

# calculate efficiency for gcc on max core for `b1_2_for_each_quadratic`
b1_2_for_each_quadratic_par_par_speed_up_64_gcc = □
    ↳ b1_2_for_each_quadratic_par_par_scaling_parbase_gcc[b1_2_for_each_quadratic_par_par_scaling
    ↳ == 64].iloc[0]['GCC(TBB)']
b1_2_data.append(b1_2_for_each_quadratic_par_par_speed_up_64_gcc)

print("\tb1_2 Speedup(64):", b1_2_for_each_quadratic_par_par_speed_up_64_gcc)

# calculate efficiency for gcc on max core for `b1_4_for_each_exponential`
```



```

b1_4_for_each_exponential_speed_up_64_gcc =
    ↪ b1_4_for_each_exponential_strong_scaling_parbase_gcc[b1_4_for_each_exponential_strong_scaling_parbase_gcc == 64].iloc[0]['GCC(TBB)']
b1_4_data.append(b1_4_for_each_exponential_speed_up_64_gcc)

print("\tb1_4 Speedup(64):", b1_4_for_each_exponential_speed_up_64_gcc)

print("\nNVC(OMP)")
# calculate efficiency for nvhpc(mc) on max core for `b1_1_for_each_linear`
b1_1_for_each_linear_speed_up_64_nvc_omp =
    ↪ b1_1_for_each_linear_strong_scaling_parbase_nvc_omp[b1_1_for_each_linear_strong_scaling_parbase_nvc_omp == 64].iloc[0]['NVC(OMP)']
b1_1_data.append(b1_1_for_each_linear_speed_up_64_nvc_omp)

print("\tb1_1 Speedup(64):", b1_1_for_each_linear_speed_up_64_nvc_omp)

# calculate efficiency for nvhpc(mc) on max core for `b1_2_for_each_quadratic`
b1_2_for_each_quadratic_par_par_speed_up_64_nvc_omp =
    ↪ b1_2_for_each_quadratic_par_par_scaling_parbase_nvc_omp[b1_2_for_each_quadratic_par_par_scaling_parbase_nvc_omp == 64].iloc[0]['NVC(OMP)']
b1_2_data.append(b1_2_for_each_quadratic_par_par_speed_up_64_nvc_omp)

print("\tb1_2 Speedup(64):",
    ↪ b1_2_for_each_quadratic_par_par_speed_up_64_nvc_omp)

# calculate efficiency for nvhpc(mc) on max core for `b1_4_for_each_exponential`
b1_4_for_each_exponential_speed_up_64_nvc_omp =
    ↪ b1_4_for_each_exponential_strong_scaling_parbase_nvc_omp[b1_4_for_each_exponential_strong_scaling_parbase_nvc_omp == 64].iloc[0]['NVC(OMP)']
b1_4_data.append(b1_4_for_each_exponential_speed_up_64_nvc_omp)
print("\tb1_4 Speedup(64):", b1_4_for_each_exponential_speed_up_64_nvc_omp)

print("\n\n")

# calc
b1_1_perfect = max(b1_1_data)
b1_2_perfect = max(b1_2_data)
b1_4_perfect = max(b1_4_data)

# Performance portability b1_1 inter compiler
b1_1_efficiency = [x / b1_1_perfect for x in b1_1_data]
pp_b1_1 = len(b1_1_efficiency) / (sum([1 / x for x in b1_1_efficiency]))

print("Performance Portability B1_1: " , pp_b1_1)

```

```

# Performance portability b1_2 inter compiler
b1_2_efficiency = [x / b1_2_perfect for x in b1_2_data]
pp_b1_2 = len(b1_2_efficiency) / (sum([1 / x for x in b1_2_efficiency]))

print("Performance Portability B1_2: " , pp_b1_2)

# Performance portability b1_4 inter compiler
b1_4_efficiency = [x / b1_4_perfect for x in b1_4_data]
pp_b1_4 = len(b1_4_efficiency) / (sum([1 / x for x in b1_4_efficiency]))

print("Performance Portability B1_4: " , pp_b1_4)

```

GCC

```

b1_1 Speedup(64): 43.03339575922877
b1_2 Speedup(64): 49.50828342574879
b1_4 Speedup(64): 29.887136604756876

```

NVC(OMP)

```

b1_1 Speedup(64): 51.12460858208368
b1_2 Speedup(64): 32.80705823482036
b1_4 Speedup(64): 1.0332712232351373

```

```

Performance Portability B1_1: 0.914067711189745
Performance Portability B1_2: 0.7971067743386567
Performance Portability B1_4: 0.0668342558082125

```

2.1.4 Findings for H1

b1_1 There is a significant runtime difference between parallel backends (TBB and NVC(OMP)) when we are dealing with quite rudimentary linear homogenous workloads. As you can see in [figure of runtime comparisons](#). The larger the input size gets the worse the performance of GCC(with TBB) gets. On the other side NVC(with OMP backend) seems to scale quite good under linear homogenous workloads.

For strong scaling we can see that calculating the speedup using the parallel implementation with 1 thread and using the sequential implementation, does not make a huge difference. In fact the overhead for this kind of workload seems to be minimal. The backends scale fairly good and the absolute speedup for each number of threads does not have a tremendous difference between the two backends. We only start to notice that the more threads we utilize the larger the speedup between GCC(TBB) and NVC(OMP) gets.

For small number of threads (1-16) we see that the speedup is quite optimal (close to perfect speedup). Only later when utilizing more threads (32+) we start to see a significant performance loss for both GCC(TBB) and NVC(OMP)

Since the performance portability metric used in this hypothesis focuses on the speedup and as

observed above and the difference between speedup is not that huge, we achieve a rather high performance portability of **91%**!

Key observations: * Significant runtime differences between GCC(TBB) and NVC(OMP) * Speedup seems to be on same level for backends only for huge number of threads it starts to degrade * Small number of threads nearly perfect speedup for both * Performance portability quite high since backends behave quite good.

b1_2 There is a significant runtime difference between parallel backends (TBB and NVC(OMP)) when we are dealing with nested quadratic parallelism (aka nested loops with each $O(n)$). As you can see in [figure of runtime comparisons](#). The larger the input size gets the worse the performance of GCC(with TBB) gets. On the other side NVC(with OMP backend) seems to scale quite good under quadratic homogenous workloads.

For this benchmark we only considered the outer parallel and inner parallel with 1thread as base to calculate the speedups. GCC(TBB) seems to have better strong scaling than NVC(OMP). It looks like that NVC(OMP) starts to degrade heavily when having high number of threads and this is also visible when looking at the efficiency.

Since the performance portability metric used in this hypothesis focuses on the speedup and as observed above and the difference between speedup is actually quite huge, we achieve a rather poor portability of **79%**!

Key observations: * Significant runtime differences between GCC(TBB) and NVC(OMP). NVC(OMP) faster than GCC(TBB) * Speedup difference becomes bigger with rise of threads. * NVC(OMP) pretty much collapses at 64 threads. * Small number of threads quite good for both backends * Performance portability poor since NVC(OMP) collapses for high number of threads.

b1_4 The runtime difference between GCC(TBB) and NVC(OMP) is extreme! Since we are dealing with exponential runtime it was expected that the runtime will increase fast, but the runtimes of NVC(OMP) exploded. At first the runtime of GCC(TBB) is worse than the of NVC(OMP), but when for larger input sizes the trend turns and the runtime of NVC(OMP) exploded and making GCC(TBB) faster by a magnitude.

For this kind of nested parallelism strong scaling does looks really bad. Using the sequential algorithm or the parallel algorithm with 1 Thread as base does not have an effect on the speedup for NVC(OMP). NVC(OMP) has really bad strong scaling and often does not even break the 1x speedup. On the other hand GCC(TBB) does improve significantly with more core reaching a speedup of more than 30x.

Since NVC(OMP) scales really bad on this kind of workload but GCC(TBB) really good, we achieve a rather poor portability of **6%**!

GPU Findings Sadly NVC(GPU) does not support nested parallelism. Although it would be possible to run **b1_1** with NVC(GPU) the rest of the benchmarks (**b1_2** and **b1_4**) do not.

Hypothesis Findings The hypothesis is TRUE!

2.2 H2

The performance is significantly impacted by the order in which parallelism is applied, whether it is outer loop sequential and inner loop parallel, or outer loop parallel and inner loop sequential.

2.2.1 Time

Time Comparison - b1_2_for_each_quadratic_outer_std::execution::sequenced_policy_par vs b1_2_for_each_quadratic_outer_std::execution::parallel_policy_seq Check how the runtime without constraining the number of threads develops with increasing the input size.

```
[28]: def get_b1_2_data_algo(compiler_location:str,compiler_name:str) -> pd.DataFrame:
    ## load b1_2_for_each_quadratic_outer_std::execution::sequenced_policy_par
    b1_2_for_each_quadratic_seq_par = extraction_pandas_frame_algo(root_dir +
    ↪f'/{compiler_location}/DEFAULT/b1_2_for_each_quadratic_outer_std::execution::
    ↪sequenced_policy_par__Default.csv',COMP=compiler_name)

    b1_2_for_each_quadratic_seq_par = b1_2_for_each_quadratic_seq_par.
    ↪drop(columns=['name','cpu_time','time_unit','median','stddev','Compiler'])
    b1_2_for_each_quadratic_seq_par = b1_2_for_each_quadratic_seq_par.
    ↪rename(columns={'real_time':f'{compiler_name} - seq_par'})

    ## load b1_2_for_each_quadratic_outer_std::execution::parallel_policy_seq
    b1_2_for_each_quadratic_par_seq = extraction_pandas_frame_algo(root_dir +
    ↪f'/{compiler_location}/DEFAULT/b1_2_for_each_quadratic_outer_std::execution::
    ↪parallel_policy_seq__Default.csv',COMP=compiler_name)

    b1_2_for_each_quadratic_par_seq = b1_2_for_each_quadratic_par_seq.
    ↪drop(columns=['name','cpu_time','time_unit','median','stddev','Compiler'])
    b1_2_for_each_quadratic_par_seq = b1_2_for_each_quadratic_par_seq.
    ↪rename(columns={'real_time':f'{compiler_name} - par_seq'})

    ## merge
    return pd.
    ↪merge(b1_2_for_each_quadratic_seq_par,b1_2_for_each_quadratic_par_seq,
    ↪on='n')

instances = [
    ('GCC_TBB','GCC(TBB)'),
    ('NVHPC_Multicore','NVC(OMP)')
]

# collect data for instances
data = [get_b1_2_data_algo(*x) for x in instances]
```

```

# merge for plotting
b1_2_for_each_quadratic_time_merged = pd.merge(*data, on='n')

# convert time from ns to microseconds because otherwise it will look really bad
for _, compiler_name in instances:
    b1_2_for_each_quadratic_time_merged[f'{compiler_name} - par_seq'] =
↳ b1_2_for_each_quadratic_time_merged[f'{compiler_name} - par_seq'] / 1_000
    b1_2_for_each_quadratic_time_merged[f'{compiler_name} - seq_par'] =
↳ b1_2_for_each_quadratic_time_merged[f'{compiler_name} - seq_par'] / 1_000

# plot
ax = b1_2_for_each_quadratic_time_merged.
↳ plot(kind='bar', x='n', align='center', color=[GCC_TBB_COLOR, GCC_TBB_COLOR_SECONDARY, NVC_OMP_C
print(b1_2_for_each_quadratic_time_merged)

# plt.yscale('log', base=10)
plt.ylabel('Time in (µs)')
plt.xlabel('Input size')
plt.title('Runtime `b1_2_for_each_quadratic` on Nebulac')

plt.show()

```

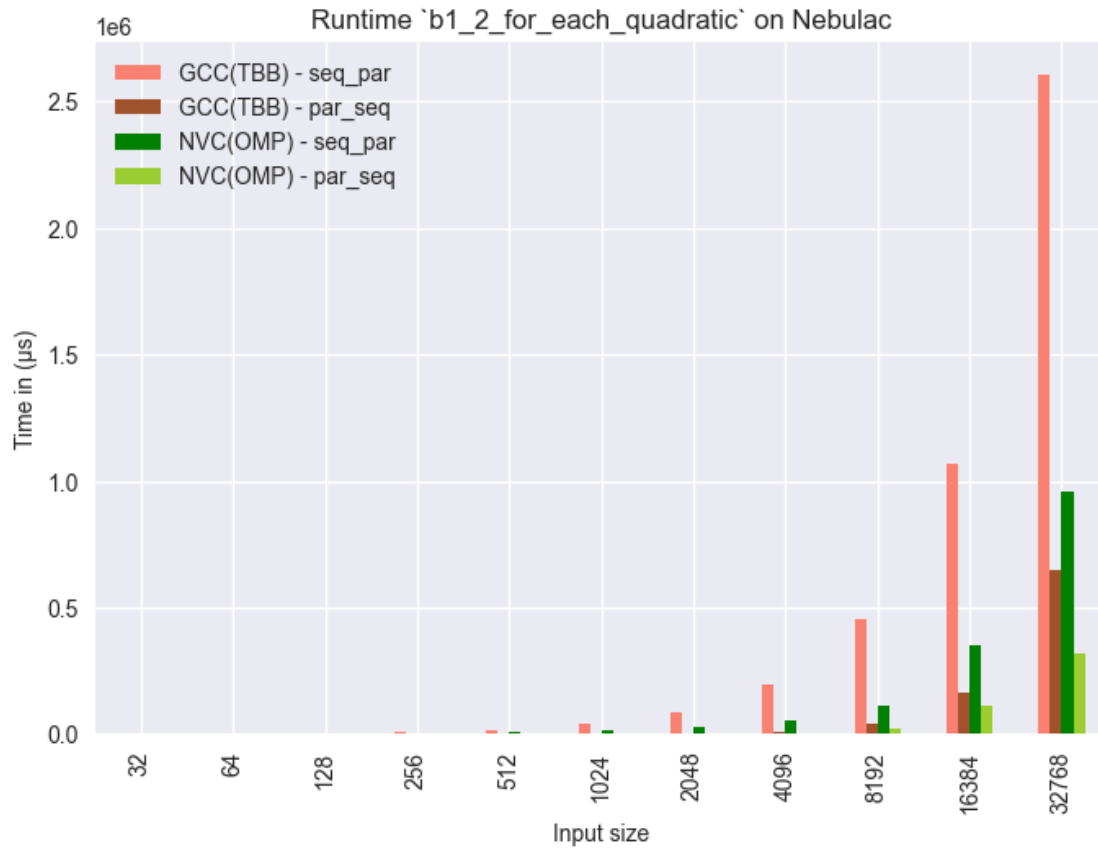
	GCC(TBB) - seq_par	n	GCC(TBB) - par_seq	NVC(OMP) - seq_par \
0	630.911	32	24.1083	350.829
1	1529.730	64	29.6303	712.506
2	3259.200	128	42.8168	1417.470
3	7237.800	256	80.5595	2827.600
4	16449.900	512	217.1550	5861.490
5	37973.700	1024	720.0160	11950.000
6	86425.400	2048	2691.5700	25747.200
7	197370.000	4096	10485.3000	52638.900
8	451837.000	8192	41183.8000	114388.000
9	1069750.000	16384	163609.0000	348804.000
10	2604950.000	32768	651184.0000	955396.000

	NVC(OMP) - par_seq
0	12.9499
1	13.3429
2	17.0725
3	32.7040
4	93.0087
5	325.7320
6	1467.6900
7	5017.4100
8	21595.6000

```

9          110340.0000
10         319242.0000

```



2.2.2 Strong Scaling

$$S(p) = T(1) / T(p)$$

As based we use once the: * parallel algorithm (1 thread)

Strong Scaling - b1_2_for_each_quadratic_outer_std::execution::sequenced_policy_par
vs b1_2_for_each_quadratic_outer_std::execution::parallel_policy_seq 32.768 fixed
input size with threads 1-64

```

[29]: def get_b1_2_strong_scaling_algo(compiler_location:str,compiler_name:str) -> pd.
      ↳ DataFrame:
          ## Threading data
          b1_2_for_each_quadratic_seq_par_threads =
      ↳ extraction_pandas_frame_algo_threaded(root_dir + f'/{compiler_location}/
      ↳ THREADS',
      ↳
      ↳ 'b1_2_for_each_quadratic_outer_std::execution::sequenced_policy_par',

```

```

↳ [1,2,4,8,16,32,64],
↳ COMP=compiler_name,
↳ input_size=32768
↳)

    ## calc strong scaling
    b1_2_for_each_quadratic_seq_par_strong_scaling =
↳calc_speedup_based_par(b1_2_for_each_quadratic_seq_par_threads,
↳f"{compiler_name} - seq_par",
↳input_size=32768
)

    ## load b1_2_for_each_quadratic_outer_std::execution::parallel_policy_seq
    b1_2_for_each_quadratic_par_seq_threads =
↳extraction_pandas_frame_algo_threaded(root_dir + f'/{compiler_location}/
↳THREADS',
↳ 'b1_2_for_each_quadratic_outer_std::execution::parallel_policy_seq',
↳ [1,2,4,8,16,32,64],
↳ COMP=compiler_name,
↳ input_size=32768
↳)

    ## calc strong scaling
    b1_2_for_each_quadratic_par_seq_strong_scaling =
↳calc_speedup_based_par(b1_2_for_each_quadratic_par_seq_threads,
↳f"{compiler_name} - par_seq",
↳input_size=32768
)

    ## merge
    return pd.merge(b1_2_for_each_quadratic_seq_par_strong_scaling,

```

```

        b1_2_for_each_quadratic_par_seq_strong_scaling,
        on='threads'
    )

instances = [
    ('GCC_TBB', 'GCC(TBB)'),
    ('NVHPC_Multicore', 'NVC(OMP)')
]

# collect data for instances
data = [get_b1_2_strong_scaling_algo(*x) for x in instances]

b1_2_for_each_quadratic_strong_scaling_merged = pd.merge(*data, on='threads')

print(b1_2_for_each_quadratic_strong_scaling_merged)

# plot strong scaling
ax = b1_2_for_each_quadratic_strong_scaling_merged.plot(kind='bar',
                                                         x='threads',
                                                         align='center',
                                                         color=[GCC_TBB_COLOR, GCC_TBB_COLOR_SECONDARY, NVC_OMP_COLOR, NVC_OMP_COLOR_SECONDARY]
                                                         )

# adding horizontal line where there is speedup
ax.axhline(y=1, color='r', linestyle='--')

plt.ylabel('Speedup')
plt.xlabel('Threads')
plt.title('Strong Scaling `b1_2_for_each_quadratic` on Nebulac (32768)')

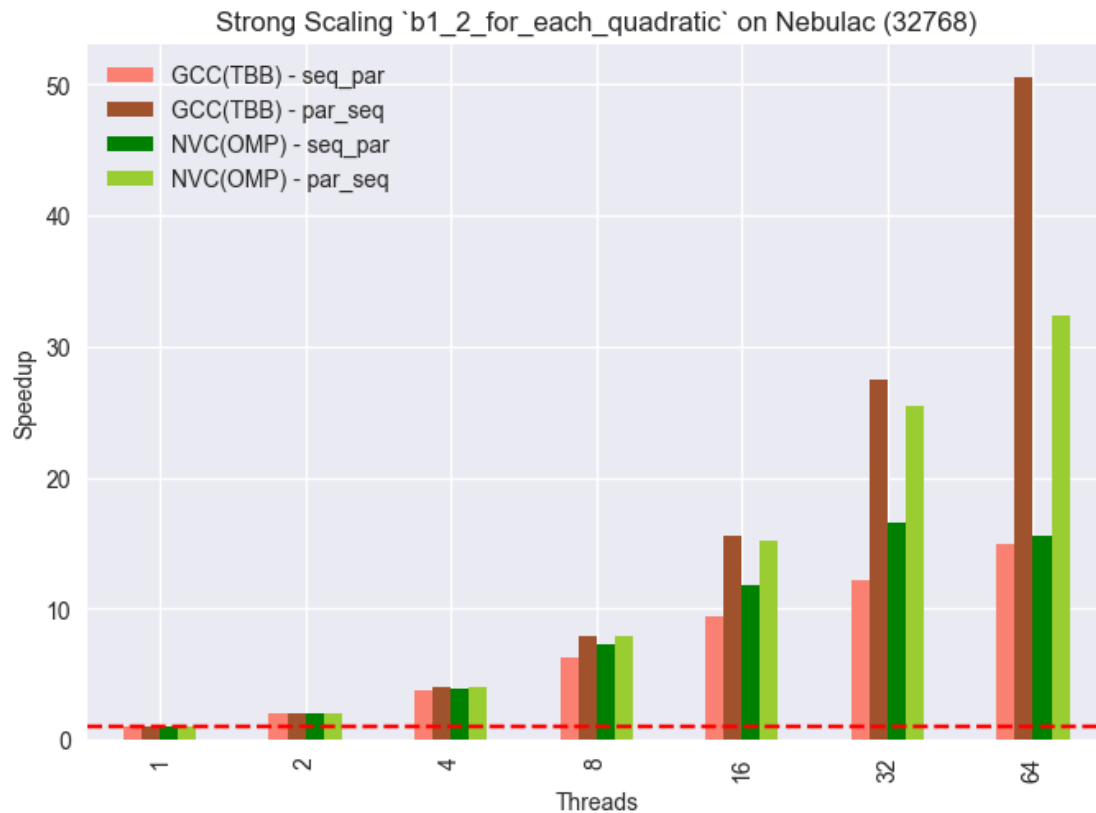
```

	threads	GCC(TBB) - seq_par	GCC(TBB) - par_seq	NVC(OMP) - seq_par \
0	1	1.000000	1.000000	1.000000
1	2	1.979862	1.998062	1.980330
2	4	3.750753	3.986084	3.855304
3	8	6.238904	7.944636	7.276533
4	16	9.478906	15.592834	11.836966
5	32	12.198081	27.519958	16.516401
6	64	14.887093	50.555355	15.592923

	NVC(OMP) - par_seq
0	1.000000
1	2.000584
2	3.987332
3	7.863144
4	15.249982


```
5         25.411051
6         32.338995
```

```
[29]: Text(0.5, 1.0, 'Strong Scaling `b1_2_for_each_quadratic` on Nebulac (32768)')
```



```
[30]: ## efficiency graph
```

```
b1_2_for_each_quadratic_efficiency = _
    ↪ b1_2_for_each_quadratic_strong_scaling_merged.copy()

instances = [
    ('GCC_TBB', 'GCC(TBB)'),
    ('NVHPC_Multicore', 'NVC(OMP)')
]

for _, compiler_name in instances:
    b1_2_for_each_quadratic_efficiency[f'{compiler_name} - par_seq'] = _
    ↪ b1_2_for_each_quadratic_efficiency[f'{compiler_name} - par_seq'] / _
    ↪ b1_2_for_each_quadratic_efficiency['threads']
```

```

    b1_2_for_each_quadratic_efficiency[f'{compiler_name} - seq_par'] =  $\frac{b1\_2\_for\_each\_quadratic\_efficiency[f'\{compiler\_name\} - seq\_par']}{b1\_2\_for\_each\_quadratic\_efficiency['threads']}$ 

print(b1_2_for_each_quadratic_efficiency)

# plot efficiency
ax = b1_2_for_each_quadratic_efficiency.plot(x='threads',
                                             color=[GCC_TBB_COLOR, GCC_TBB_COLOR_SECONDARY, NVC_OMP_COLOR, NVC_OMP_COLOR_SECONDARY])

# adding horizontal line where there is speedup
ax.axhline(y=1, color='r', linestyle='--')

plt.ylim(0,1.05)

plt.xscale('log', base=2)
current_values = plt.gca().get_xticks()
plt.gca().set_xticklabels(['{:,.0f}'.format(x) for x in current_values])

plt.ylabel('Efficiency')
plt.xlabel('Threads')
plt.title('Efficiency `b1_2_for_each_quadratic` on Nebulac (32768)')

plt.show()

```

	threads	GCC(TBB) - seq_par	GCC(TBB) - par_seq	NVC(OMP) - seq_par \
0	1	1.000000	1.000000	1.000000
1	2	0.989931	0.999031	0.990165
2	4	0.937688	0.996521	0.963826
3	8	0.779863	0.993079	0.909567
4	16	0.592432	0.974552	0.739810
5	32	0.381190	0.859999	0.516138
6	64	0.232611	0.789927	0.243639

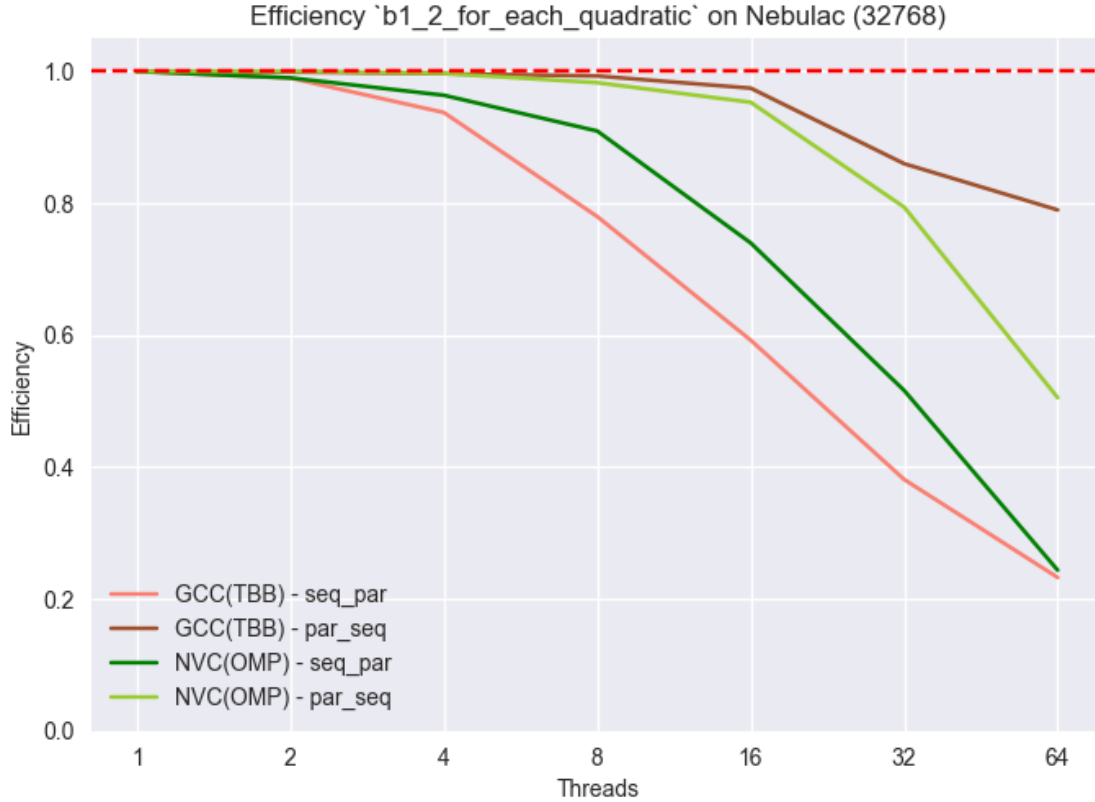
	NVC(OMP) - par_seq
0	1.000000
1	1.000292
2	0.996833
3	0.982893
4	0.953124
5	0.794095
6	0.505297

```

/var/folders/42/fk0jfryd1dd1ztdldncqc1cw0000gn/T/ipykernel_5746/3822859030.py:30
: UserWarning: FixedFormatter should only be used together with FixedLocator

```

```
plt.gca().set_xticklabels(['{:,.0f}'.format(x) for x in current_values])
```



2.2.3 Performance Portability Calculation (Inter Compiler)

Since we know that (par, seq) will be better than (seq, par) we can check the stddev of the performance improvement from (seq, par) to (par, seq) for every compiler. For example:

	(seq, par)	(par, seq)	faster
GCC(TBB)	10s	5s	2x
NVC(OMP)	12s	8s	1.5x
NVC(GPU)	0	0	0
Intel	9	1	9x

$\text{stddev}(2, 1.5, 9) = 3.4$ indicating that the difference is quite significant when changing compilers.

$\text{stddev}(2, 1.5) = 0.25$ indicating that the difference is not significant when changing compilers.

```
[31]: # calc pp_metrics

instances = [
    ('GCC_TBB', 'GCC(TBB)'),
    ('NVHPC_Multicore', 'NVC(OMP)')
```

```

]

faster_data = []

for compiler_location, compiler_name in instances:
    print(compiler_name)

    times_faster = (b1_2_for_each_quadratic_time_merged[f'{compiler_name} -_
↪seq_par'] / b1_2_for_each_quadratic_time_merged[f'{compiler_name} -_
↪par_seq']).iloc[-1]
    faster_data.append(times_faster)

    print("\t Par_Seq faster than Seq_Par: ", times_faster)
    print()

print("\n")
pp_h2 = statistics.stdev(faster_data)

print("Performance Portability H2:", pp_h2)

```

GCC(TBB)

Par_Seq faster than Seq_Par: 4.000328632153124

NVC(OMP)

Par_Seq faster than Seq_Par: 2.9927014615871346

Performance Portability H2: 0.7125000052150252

2.2.4 Findings for H2

b1_2_for_each_quadratic_outer_std::execution::sequenced_policy_par (seq_par) The performance of seq_par exhibits significant variations when switching between compilers, particularly for larger input sizes of 8192+. The runtime differences become increasingly worse, and GCC(TBB) demonstrates poor performance in such scenarios.

As for strong scaling, seq_par's performance is rather poor. Both GCC(TBB) and NVC(OMP) experience a poor speedup after 16 threads. While GCC(TBB) exhibits minor improvements with additional threads, they are insignificant. On the other hand NVC(OMP) loses speedup once 64 threads are used. The efficiency graph shows that NVC(OMP) takes a hit at 8 threads, with both collapsing at 16 threads. Notably, NVC(OMP) starts from a higher efficiency level than GCC(TBB).

Key Observations: * Runtime of seq_par changes a lot from compiler to compiler * GCC(TBB) performs really bad (runtime) * Strong scaling of GCC(TBB) is better than NVC(OMP) * NVC(OMP) strong scaling even worse when going 32->64 threads

b1_2_for_each_quadratic_outer_std::execution::parallel_policy_seq (par_seq) We see the same behaviour here as seen when using seq_par. Notably, as the input sizes increase, GCC(TBB) shows a more rapid decline in performance compared to NVC(OMP). For instance, when transitioning from 16k to 32k, NVC(OMP) experiences a speedup of **2.89x**, whereas GCC(TBB) only shows a speedup of **3.98x**.

Moreover, the two backends exhibit different behavior when strong scaling. As the number of threads increases, GCC(TBB) benefits from the added resources, while NVC(OMP) takes a considerable hit and reaches peak performance at 32 threads.

Key Observations: * Runtime difference visible (when changing compiler) * GCC(TBB) runtime explodes for large input size * NVC(OMP) runtime rises as expected for large input sizes * GCC(TBB) strong scaling way better than NVC(OMP) * NVC(OMP) strong scaling starts to slow down at 32 threads

2.2.5 General

We can observe a significant difference in runtime when we switch between execution policies for inner and outer loops. This behavior is consistent across all parallel backends. In terms of runtime, GCC(TBB) shows the most substantial improvement when switching from seq_par to par_seq. However, NVC(OMP) performs better in absolute runtime numbers.

Switching from seq_par to par_seq also affects strong scaling. For smaller input sizes, the backends show similar strong scaling behavior. However, for larger thread counts (64), GCC(TBB) still shows improvements over NVC(OMP).

When switching between backends, all of them show improvement, though to varying degrees. The extent of improvement differs between the backends, as reflected in the performance portability metric calculated for this benchmark. The stddev value of 0.71 indicates that changing compilers can lead to better performance improvements.

Key Observation: * Changing order of execution policy has great impact. * Strong Scaling varies a lot by compiler * Absolute Runtime difference by compiler is a lot * Improvement from seq_par to par_seq varies significantly by compiler

GPU Findings Sadly because this benchmarks use nested parallelism it won't work on the NVC(GPU).

Hypothesis Findings This hypothesis is **TRUE!**