pi_value

January 24, 2024

1 Assignment 2

Write a program for Leibniz series for PI calculation to demonstrate the performance enhancement done by parallelizing the code through Open MP work-sharing of loops. * Implement the code with different thread count and different maximum number of terms to be calculated for the series such as thread count 10, 20 and terms 100, 1000, 10000, 1000000. * Display a visualization of performance comparison between serial and parallel, a visual analysis of delay/speedup with the help of varying thread counts and maximum terms in the series for Pi value calculation.

[1]:
```
import numpy as np
import threading
import time
import pandas as pd
import matplotlib.pyplot as plt
```

[2]:
```
# using another method leibniz
```

[3]:
```
def estimate_pi_leibniz_sequential(num_terms):
    pi_estimate = 0

    start_time = time.time()

    for k in range(num_terms):
        term = (-1) ** k / (2 * k + 1)
        pi_estimate += term

    pi_estimate *= 4

    end_time = time.time()
    elapsed_time = end_time - start_time

    return pi_estimate, elapsed_time
```

[4]:
```
num_terms_list = [100, 500, 700, 1000, 5000, 10000, 1000000]
pi_estimates = []
elapsed_times = []
```

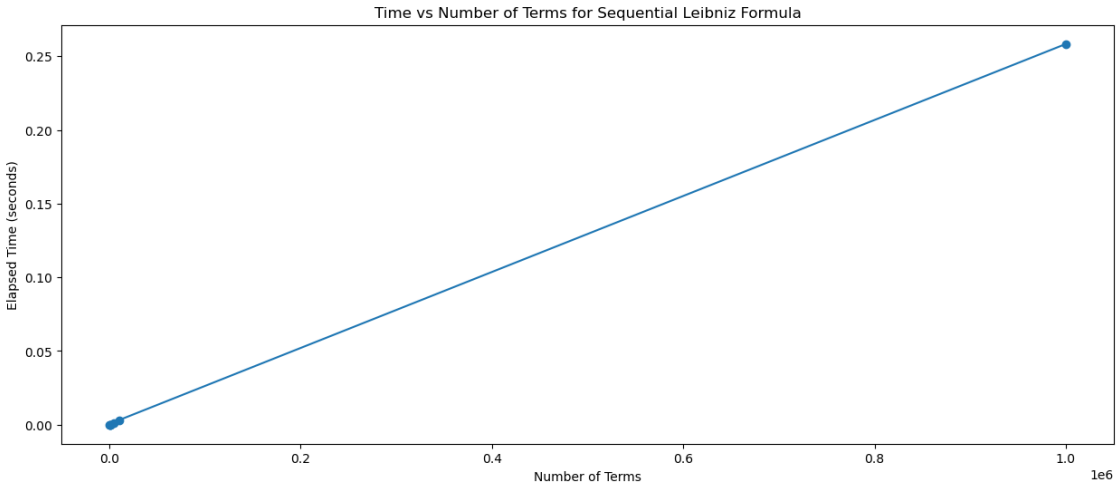
[5]:
```
for num_terms in num_terms_list:
    pi_estimate, elapsed_time = estimate_pi_leibniz_sequential(num_terms)
    pi_estimates.append(pi_estimate)
    elapsed_times.append(elapsed_time)
    print(f"Number of Terms: {num_terms}, Estimated Pi: {pi_estimate}, Elapsed␣
 ↪Time: {elapsed_time:.6f} seconds")
```

```
Number of Terms: 100, Estimated Pi: 3.1315929035585537, Elapsed Time: 0.000000
seconds
Number of Terms: 500, Estimated Pi: 3.139592655589785, Elapsed Time: 0.000000
seconds
Number of Terms: 700, Estimated Pi: 3.1401640828900845, Elapsed Time: 0.000000
seconds
Number of Terms: 1000, Estimated Pi: 3.140592653839794, Elapsed Time: 0.000000
seconds
Number of Terms: 5000, Estimated Pi: 3.141392653591791, Elapsed Time: 0.001000
seconds
Number of Terms: 10000, Estimated Pi: 3.1414926535900345, Elapsed Time: 0.003065
seconds
Number of Terms: 1000000, Estimated Pi: 3.1415916535897743, Elapsed Time:
0.258360 seconds
```

[6]:
```
# Plotting the results
plt.figure(figsize=(15, 6))

plt.plot(num_terms_list, elapsed_times, marker='o')
plt.title('Time vs Number of Terms for Sequential Leibniz Formula')
plt.xlabel('Number of Terms')
plt.ylabel('Elapsed Time (seconds)')

plt.show()
```



[7]:
```
# using math module
```

[8]:
```
import math
```

[9]:
```
def calculate_pi():
    start_time = time.time()

    # Accessing the built-in pi constant
    pi_estimate = math.pi

    end_time = time.time()
    elapsed_time = end_time - start_time

    return pi_estimate, elapsed_time
```

[10]:
```
num_terms_list = [100, 500, 1000, 5000, 10000, 1000000]
pi_estimates_builtin = []
elapsed_times_builtin = []
```

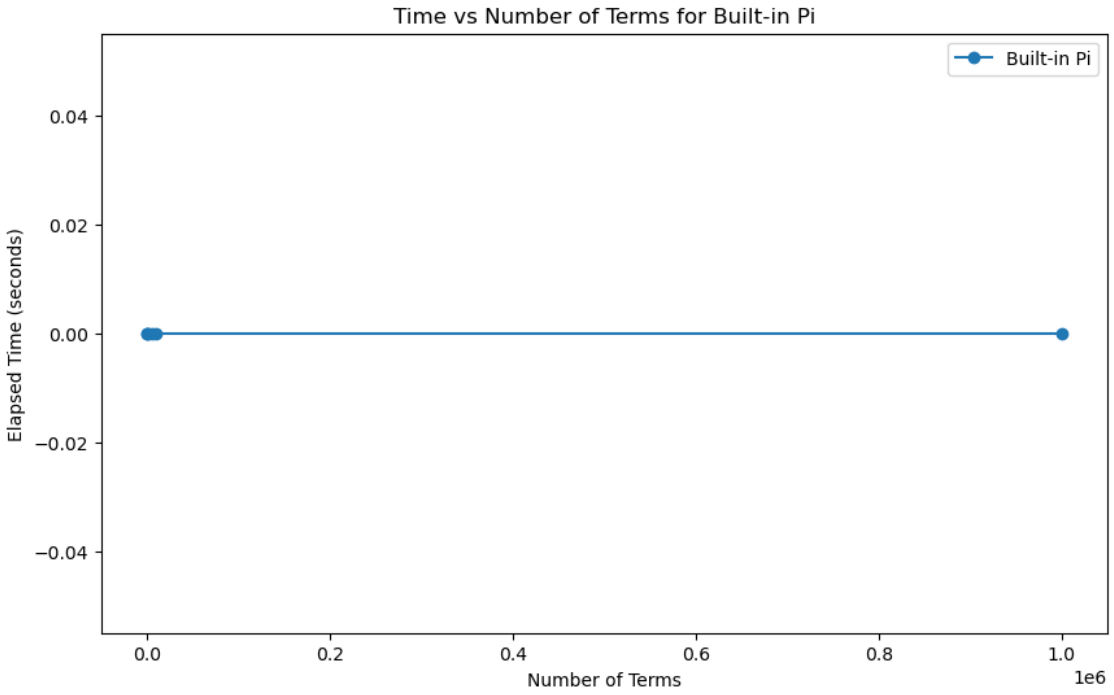
[11]:
```
for num_terms in num_terms_list:
    pi_estimate, elapsed_time = calculate_pi()
    pi_estimates_builtin.append(pi_estimate)
    elapsed_times_builtin.append(elapsed_time)
    print(f"Number of Terms: {num_terms}, Built-in Pi: {pi_estimate}, Elapsed␣
 ↪Time: {elapsed_time:.6f} seconds")
```

```
Number of Terms: 100, Built-in Pi: 3.141592653589793, Elapsed Time: 0.000000
seconds
Number of Terms: 500, Built-in Pi: 3.141592653589793, Elapsed Time: 0.000000
seconds
Number of Terms: 1000, Built-in Pi: 3.141592653589793, Elapsed Time: 0.000000
seconds
Number of Terms: 5000, Built-in Pi: 3.141592653589793, Elapsed Time: 0.000000
seconds
Number of Terms: 10000, Built-in Pi: 3.141592653589793, Elapsed Time: 0.000000
seconds
Number of Terms: 1000000, Built-in Pi: 3.141592653589793, Elapsed Time: 0.000000
seconds
```

[12]:
```
# Plotting the results
plt.figure(figsize=(10, 6))

plt.plot(num_terms_list, elapsed_times_builtin, marker='o', label='Built-in Pi')
plt.title('Time vs Number of Terms for Built-in Pi')
plt.xlabel('Number of Terms')
plt.ylabel('Elapsed Time (seconds)')
plt.legend()
```

```
plt.show()
```



[13]:
```
# parallel processing
```

[14]:
```
def estimate_pi_leibniz_parallel(num_terms, num_threads):
    pi_estimate = 0
    terms_per_thread = num_terms // num_threads
    threads = []

    def calculate_terms(start, end):
        nonlocal pi_estimate
        for k in range(start, end):
            term = (-1) ** k / (2 * k + 1)
            pi_estimate += term

    start_time = time.time()

    for i in range(num_threads):
        start = i * terms_per_thread
        end = (i + 1) * terms_per_thread if i < num_threads - 1 else num_terms
        thread = threading.Thread(target=calculate_terms, args=(start, end))
        thread.start()
        threads.append(thread)
```

```
    for thread in threads:
        thread.join()

    pi_estimate *= 4

    end_time = time.time()
    elapsed_time = end_time - start_time

    return pi_estimate, elapsed_time
```

[15]:
```
num_terms_list = [100, 500, 1000, 5000, 10000, 1000000]
num_threads_list = [2, 4, 8, 10, 20]
pi_estimates_parallel = []
elapsed_times_parallel = []
```

[16]:
```
for num_terms in num_terms_list:
    for num_threads in num_threads_list:
        pi_estimate, elapsed_time = estimate_pi_leibniz_parallel(num_terms,␣
 ↪num_threads)
        pi_estimates_parallel.append(pi_estimate)
        elapsed_times_parallel.append(elapsed_time)
        print(f"Number of Terms: {num_terms}, Threads: {num_threads}, Estimated␣
 ↪Pi: {pi_estimate}, Elapsed Time: {elapsed_time:.6f} seconds")
```

```
Number of Terms: 100, Threads: 2, Estimated Pi: 3.1315929035585537, Elapsed
Time: 0.000925 seconds
Number of Terms: 100, Threads: 4, Estimated Pi: 3.1315929035585537, Elapsed
Time: 0.002008 seconds
Number of Terms: 100, Threads: 8, Estimated Pi: 3.1315929035585537, Elapsed
Time: 0.002308 seconds
Number of Terms: 100, Threads: 10, Estimated Pi: 3.1315929035585537, Elapsed
Time: 0.004260 seconds
Number of Terms: 100, Threads: 20, Estimated Pi: 3.1315929035585537, Elapsed
Time: 0.005051 seconds
Number of Terms: 500, Threads: 2, Estimated Pi: 3.139592655589785, Elapsed Time:
0.001016 seconds
Number of Terms: 500, Threads: 4, Estimated Pi: 3.139592655589785, Elapsed Time:
0.001000 seconds
Number of Terms: 500, Threads: 8, Estimated Pi: 3.139592655589785, Elapsed Time:
0.001270 seconds
Number of Terms: 500, Threads: 10, Estimated Pi: 3.139592655589785, Elapsed
Time: 0.002385 seconds
Number of Terms: 500, Threads: 20, Estimated Pi: 3.139592655589785, Elapsed
Time: 0.003964 seconds
Number of Terms: 1000, Threads: 2, Estimated Pi: 3.140592653839794, Elapsed
Time: 0.000000 seconds
Number of Terms: 1000, Threads: 4, Estimated Pi: 3.140592653839794, Elapsed
Time: 0.001036 seconds
```

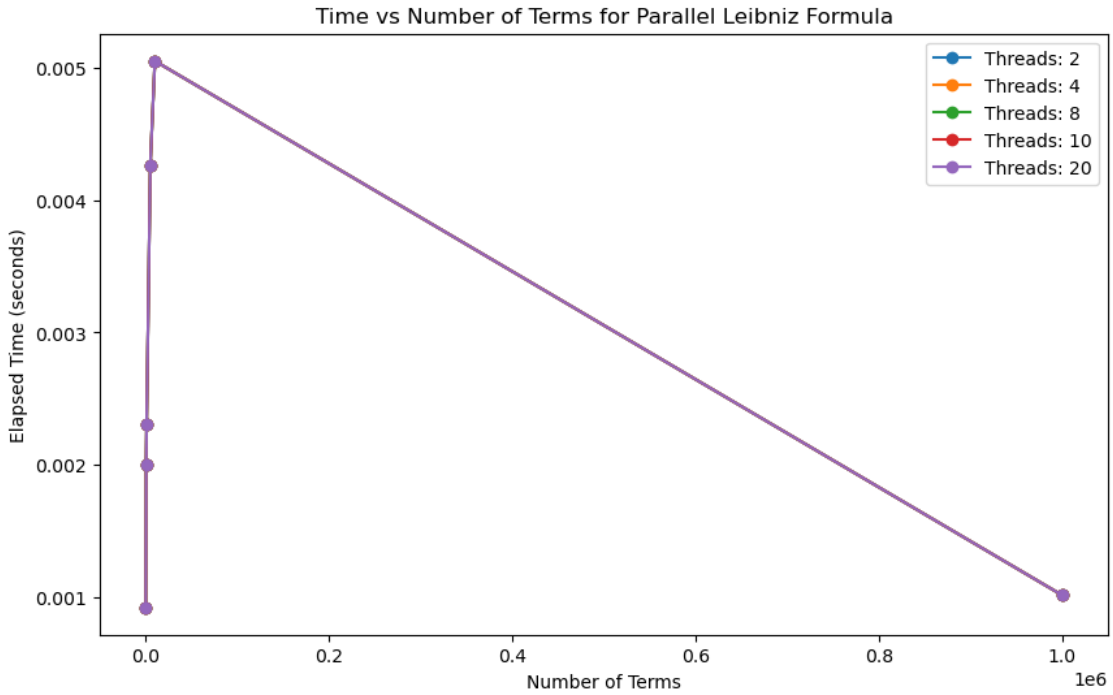
```
Number of Terms: 1000, Threads: 8, Estimated Pi: 3.140592653839794, Elapsed
Time: 0.001727 seconds
Number of Terms: 1000, Threads: 10, Estimated Pi: 3.140592653839794, Elapsed
Time: 0.002029 seconds
Number of Terms: 1000, Threads: 20, Estimated Pi: 3.140592653839794, Elapsed
Time: 0.003388 seconds
Number of Terms: 5000, Threads: 2, Estimated Pi: 3.141392653591791, Elapsed
Time: 0.001691 seconds
Number of Terms: 5000, Threads: 4, Estimated Pi: 3.141392653591791, Elapsed
Time: 0.001998 seconds
Number of Terms: 5000, Threads: 8, Estimated Pi: 3.141392653591791, Elapsed
Time: 0.002791 seconds
Number of Terms: 5000, Threads: 10, Estimated Pi: 3.141392653591791, Elapsed
Time: 0.003022 seconds
Number of Terms: 5000, Threads: 20, Estimated Pi: 3.141392653591791, Elapsed
Time: 0.004476 seconds
Number of Terms: 10000, Threads: 2, Estimated Pi: 3.1414926535900345, Elapsed
Time: 0.003020 seconds
Number of Terms: 10000, Threads: 4, Estimated Pi: 3.1414926535900345, Elapsed
Time: 0.003651 seconds
Number of Terms: 10000, Threads: 8, Estimated Pi: 3.1414926535900345, Elapsed
Time: 0.003251 seconds
Number of Terms: 10000, Threads: 10, Estimated Pi: 3.1414926535900345, Elapsed
Time: 0.003179 seconds
Number of Terms: 10000, Threads: 20, Estimated Pi: 3.1414926535900345, Elapsed
Time: 0.004920 seconds
Number of Terms: 1000000, Threads: 2, Estimated Pi: 3.141591653589775, Elapsed
Time: 0.270748 seconds
Number of Terms: 1000000, Threads: 4, Estimated Pi: 3.141591653589774, Elapsed
Time: 0.267083 seconds
Number of Terms: 1000000, Threads: 8, Estimated Pi: 3.1415916535897734, Elapsed
Time: 0.270692 seconds
Number of Terms: 1000000, Threads: 10, Estimated Pi: 3.1415916535897743, Elapsed
Time: 0.277053 seconds
Number of Terms: 1000000, Threads: 20, Estimated Pi: 3.141591653589774, Elapsed
Time: 0.275397 seconds
```

[17]:
```python
plt.figure(figsize=(10, 6))

for num_threads in num_threads_list:
    plt.plot(num_terms_list, elapsed_times_parallel[:len(num_terms_list)],␣
 ↪marker='o', label=f'Threads: {num_threads}')

plt.title('Time vs Number of Terms for Parallel Leibniz Formula')
plt.xlabel('Number of Terms')
plt.ylabel('Elapsed Time (seconds)')
plt.legend()
```

```
plt.show()
```


Time vs Number of Terms for Parallel Leibniz Formula
Threads: 2
Threads: 4
Threads: 8
Threads: 10
Threads: 20
Elapsed Time (seconds)
0.005
0.004
0.003
0.002
0.001
0.0
0.2
0.4
0.6
0.8
1.0
1e6
Number of Terms