

EP2

July 10, 2020

1 EP2: CUDA & OpenMPI

1.1 Entrega do EP2

Preencha o nome dos 5 membros do seu grupo na tabela abaixo:

Nome	NUSP
André Akira Hayashi	9293011
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Renan Tiago dos Santos Silva	9793606
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Bruno Picoli Romano	6402851

```
[1]: ] up
```

```
Updating registry at `~/julia/registries/General`
```

```
Updating git-repo  
`https://github.com/JuliaRegistries/General.git`
```

```
Updating `~/julia/environments/v1.4/Project.toml`  
[8314cec4] ↑ PGFPlotsX v1.2.6 v1.2.8  
Updating `~/julia/environments/v1.4/Manifest.toml`  
[8314cec4] ↑ PGFPlotsX v1.2.6 v1.2.8
```

```
[2]: import Pkg;  
Pkg.add("DataFrames")  
Pkg.add("CSV")  
Pkg.add(Pkg.PackageSpec(;name="PGFPlotsX", version="1.2.6"))  
Pkg.build("PGFPlotsX")  
Pkg.add("Plots")  
Pkg.add("Query")  
Pkg.add("StatsPlots")
```

```
Resolving package versions...
```

```

    Updating `~/.julia/environments/v1.4/Project.toml`
[no changes]
    Updating `~/.julia/environments/v1.4/Manifest.toml`
[no changes]
    Resolving package versions...
    Updating `~/.julia/environments/v1.4/Project.toml`
[no changes]
    Updating `~/.julia/environments/v1.4/Manifest.toml`
[no changes]
    Resolving package versions...
    Updating `~/.julia/environments/v1.4/Project.toml`
[8314cec4] ↓ PGFPlotsX v1.2.8 v1.2.6
    Updating `~/.julia/environments/v1.4/Manifest.toml`
[8314cec4] ↓ PGFPlotsX v1.2.8 v1.2.6
    Resolving package versions...
    Updating `~/.julia/environments/v1.4/Project.toml`
[no changes]
    Updating `~/.julia/environments/v1.4/Manifest.toml`
[no changes]
    Resolving package versions...
    Updating `~/.julia/environments/v1.4/Project.toml`
[no changes]
    Updating `~/.julia/environments/v1.4/Manifest.toml`
[no changes]
    Resolving package versions...
    Updating `~/.julia/environments/v1.4/Project.toml`
[no changes]
    Updating `~/.julia/environments/v1.4/Manifest.toml`
[no changes]

```

```
[3]: ] st
```

```

Status `~/.julia/environments/v1.4/Project.toml`
 [336ed68f] CSV v0.7.3
 [a93c6f00] DataFrames v0.21.4
 [7073ff75] IJulia v1.21.2
 [8314cec4] PGFPlotsX v1.2.6
 [91a5bcd] Plots v1.5.4
 [1a8c2f83] Query v0.12.2
 [f3b207a7] StatsPlots v0.14.6

```

1.1.1 Função de leitura para arquivos .csv

```

[4]: using CSV

function read_csv_results(filename)
    copy = CSV.read(filename)
    return copy

```

```
end
```

[4]: read_csv_results (generic function with 1 method)

1.1.2 Funções Parse

```
[5]: using DataFrames, Query, StatsPlots, Statistics
function parse_results_threads(results)
    parsed_results = results |>
        @groupby(_.threads) |>
        @map({threads = key(_),
              mean_time = mean(_.time_elapsed),
              ci_time = 1.96 * std(_.time_elapsed)}) |>
        DataFrame

    return parsed_results
end

function parse_results_iteration(results)
    parsed_results = results |>
        @groupby(_.iteration) |>
        @map({iteration = key(_),
              mean_time = mean(_.time_elapsed),
              ci_time = 1.96 * std(_.time_elapsed)}) |>
        DataFrame

    return parsed_results
end
```

[5]: parse_results_iteration (generic function with 1 method)

1.1.3 Leitura e parse dos resultados sequenciais

```
[6]: seq_triple_spiral = read_csv_results("results_seq_triple_spiral_noio.csv")
    parsed_threads_seq_triple_spiral = (parse_results_threads(seq_triple_spiral))
    parsed_iteration_seq_triple_spiral =
        ↪(parse_results_iteration(seq_triple_spiral))
```

```
Warning: `CSV.read(input; kw...)` is deprecated in favor of
`DataFrame!(CSV.File(input; kw...))`
@ CSV /home/akira/.julia/packages/CSV/W9RT2/src/CSV.jl:40
```

[6]:

	iteration	mean_time	ci_time
	Int64	Float64	Float64
1	1	22.1969	NaN
2	2	22.3583	NaN
3	3	22.1904	NaN
4	4	22.1909	NaN
5	5	22.1964	NaN
6	6	22.1899	NaN
7	7	22.1931	NaN
8	8	22.1983	NaN

1.1.4 Leitura e parse dos resultados de Pthreads e OpenMP

```
[7]: pth_triple_spiral = read_csv_results("results_pth_triple_spiral_noio.csv")
      parsed_threads_pth_triple_spiral = (parse_results_threads(pth_triple_spiral))
      parsed_iteration_pth_triple_spiral = ␣
      ↪(parse_results_iteration(pth_triple_spiral))

      omp_triple_spiral = read_csv_results("results_omp_triple_spiral_noio.csv")
      parsed_threads_omp_triple_spiral = (parse_results_threads(omp_triple_spiral))
      parsed_iteration_omp_triple_spiral = ␣
      ↪(parse_results_iteration(omp_triple_spiral))
```

```
Warning: `CSV.read(input; kw...)` is deprecated in favor of
`DataFrame!(CSV.File(input; kw...))`
 @ CSV /home/akira/.julia/packages/CSV/W9RT2/src/CSV.jl:40
Warning: `CSV.read(input; kw...)` is deprecated in favor of
`DataFrame!(CSV.File(input; kw...))`
 @ CSV /home/akira/.julia/packages/CSV/W9RT2/src/CSV.jl:40
```

```
[7]:
```

	iteration	mean_time	ci_time
	Int64	Float64	Float64
1	1	10.2685	12.2909
2	2	10.2721	12.2465
3	3	10.2795	12.2408
4	4	10.2927	12.2121
5	5	10.3164	12.2111
6	6	10.3156	12.177
7	7	10.3254	12.1858
8	8	10.3294	12.1734

1.1.5 Leitura e parse dos resultados do CUDA

```
[8]: cuda_triple_spiral = read_csv_results("results_cuda_triple_spiral.csv")
      parsed_threads_cuda_triple_spiral = (parse_results_threads(cuda_triple_spiral))
      parsed_iteration_cuda_triple_spiral = ␣
      ↪(parse_results_iteration(cuda_triple_spiral))
```

Warning: `CSV.read(input; kw...)` is deprecated in favor of
`DataFrame!(CSV.File(input; kw...))`
@ CSV /home/akira/.julia/packages/CSV/W9RT2/src/CSV.jl:40

[8]:

	iteration	mean_time	ci_time
	Int64	Float64	Float64
1	1	0.710512	0.0334223
2	2	0.710862	0.0135739
3	3	0.719982	0.02325
4	4	0.71256	0.0261993
5	5	0.70973	0.0275163
6	6	0.720868	0.0186025
7	7	0.72845	0.0190411
8	8	0.727308	0.0222488

1.1.6 Leitura e parse dos resultados do OMPI

[9]:

```

ompi_triple_spiral = read_csv_results("results_ompi_triple_spiral.csv")
parsed_threads_ompi_triple_spiral = (parse_results_threads(ompi_triple_spiral))
parsed_iteration_ompi_triple_spiral =
↳ (parse_results_iteration(ompi_triple_spiral))

```

Warning: `CSV.read(input; kw...)` is deprecated in favor of
`DataFrame!(CSV.File(input; kw...))`
@ CSV /home/akira/.julia/packages/CSV/W9RT2/src/CSV.jl:40

[9]:

	iteration	mean_time	ci_time
	Int64	Float64	Float64
1	1	9.83536	11.4659
2	2	9.84052	11.5043
3	3	9.81962	11.498
4	4	9.82162	11.4967
5	5	9.82236	11.4868
6	6	9.83923	11.4725
7	7	9.82042	11.5048
8	8	9.83832	11.4662

1.1.7 Funções Plot

[10]:

```

using Plots
pgfplotsx()

function plot_results_iteration(x, y, x_label, y_label, series_label; yerror =
↳ [], max_size_iteration)
    if yerror != []
        p = scatter(x,
            y,
            xlabel = x_label,
            ylabel = y_label,

```

```

        xticks = [x for x in 1:max_size_iteration],
        yerror = yerror,
        alpha = 0.6,
        labels = series_label,
        legend = :top)
    else
        p = scatter(x,
            y,
            xlabel = x_label,
            ylabel = y_label,
            xticks = [x for x in 1:max_size_iteration],
            alpha = 0.6,
            labels = series_label,
            legend = :top)
    end

    return p
end

function plot_results_thread(x, y, x_label, y_label, series_label; yerror = [],
    ↪max_thread_power = 1)
    if yerror != []
        p = scatter(x,
            y,
            xaxis = :log2,
            xlabel = x_label,
            ylabel = y_label,
            xticks = [2^x for x in 1:max_thread_power],
            yerror = yerror,
            alpha = 0.6,
            labels = series_label,
            legend = :topright)
    else
        p = scatter(x,
            y,
            xaxis = :log2,
            xlabel = x_label,
            ylabel = y_label,
            xticks = [2^x for x in 1:max_thread_power],
            alpha = 0.6,
            labels = series_label,
            legend = :topright)
    end

    return p
end

```

```
[10]: plot_results_thread (generic function with 1 method)
```

1.2 Gráficos

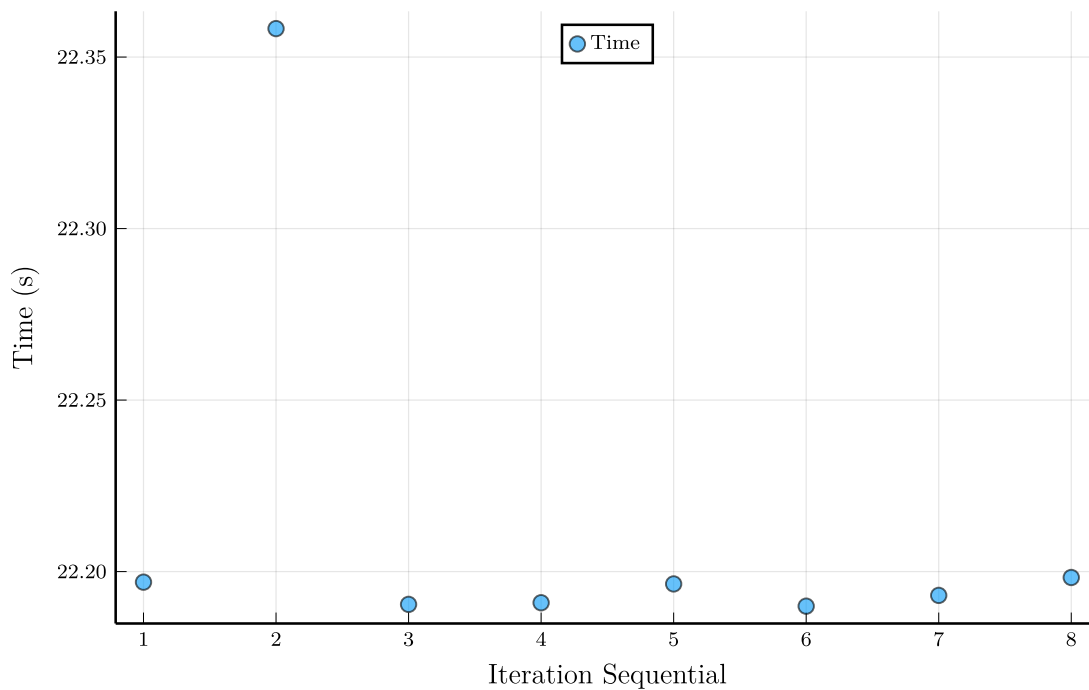
Os gráficos foram gerados rodando as versões sem I/O, com 15 repetições, tamanho da imagem igual a 4096, e na região Triple Spiral Valley, além de realizar 8 iterações sobre o mesmo código, para que fosse obtido uma maior amostra para a produção dos gráficos.

1.3 Gráficos Sequencial

1.3.1 Tempo x Iterações

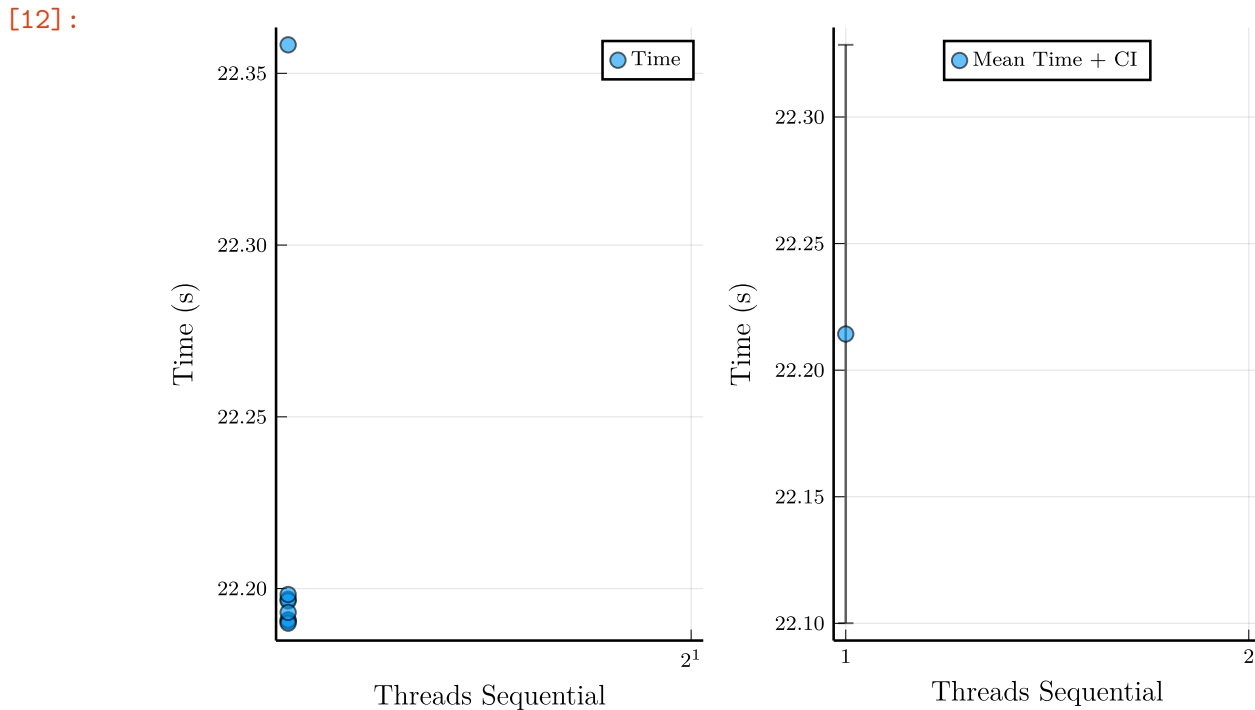
```
[11]: p1 = plot_results_iteration(seq_triple_spiral.iteration,  
    seq_triple_spiral.time_elapsed,  
    "Iteration Sequential",  
    "Time (s)",  
    "Time",  
    max_size_iteration = 8)  
plot(p1)
```

```
[11]:
```



1.3.2 Tempo x Threads

```
[12]: p1 = plot_results_thread(seq_triple_spiral.threads,
    seq_triple_spiral.time_elapsed,
    "Threads Sequential",
    "Time (s)",
    "Time",
    max_thread_power = 1)
p2 = plot_results_iteration(parsed_threads_seq_triple_spiral.threads,
    parsed_threads_seq_triple_spiral.mean_time,
    "Threads Sequential",
    "Time (s)",
    "Mean Time + CI",
    yerror = parsed_threads_seq_triple_spiral.ci_time,
    max_size_iteration = 8)
plot(p1, p2)
```



1.4 Gráficos Pthread

1.4.1 Tempo x Iterações

```
[13]: p1 = plot_results_iteration(pth_triple_spiral.iteration,
    pth_triple_spiral.time_elapsed,
    "Iteration Pthread",
    "Time (s)",
```

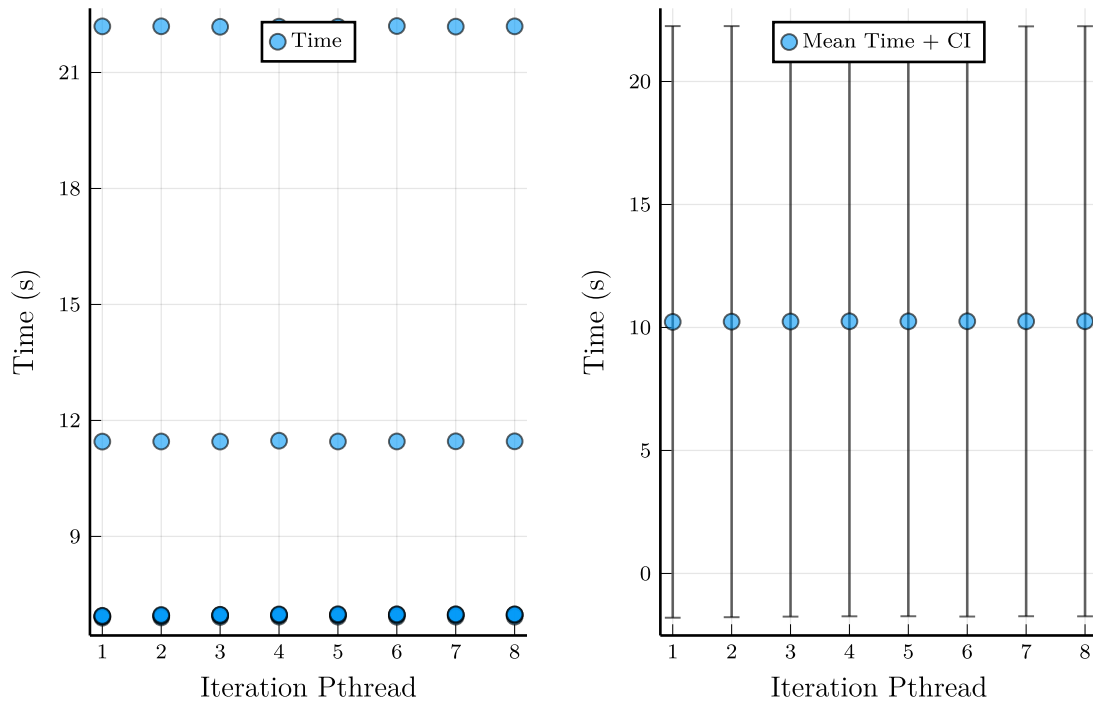


```

    "Time",
    max_size_iteration = 8)
p2 = plot_results_iteration(parsed_iteration_pth_triple_spiral.iteration,
    parsed_iteration_pth_triple_spiral.mean_time,
    "Iteration Pthread",
    "Time (s)",
    "Mean Time + CI",
    yerror = parsed_iteration_pth_triple_spiral.ci_time,
    max_size_iteration = 8)
plot(p1,p2)

```

[13]:



1.4.2 Tempo x Threads

```

[14]: p1 = plot_results_thread(pth_triple_spiral.threads,
    pth_triple_spiral.time_elapsed,
    "Threads Pthread",
    "Time (s)",
    "Time",
    max_thread_power = 5)
p2 = plot_results_thread(parsed_threads_pth_triple_spiral.threads,
    parsed_threads_pth_triple_spiral.mean_time,
    "Threads Pthread",
    "Time (s)",

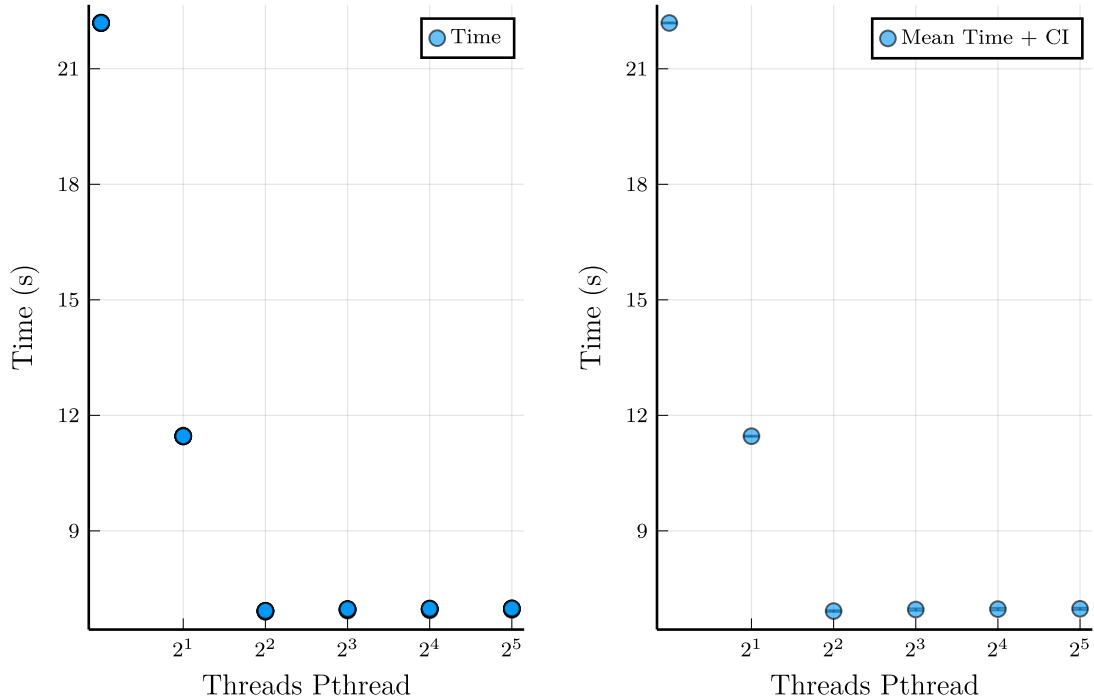
```

```

    "Mean Time + CI",
    yerror = parsed_threads_pth_triple_spiral.ci_time,
    max_thread_power = 5)
plot(p1,p2)

```

[14]:



1.5 Gráficos OpenMP

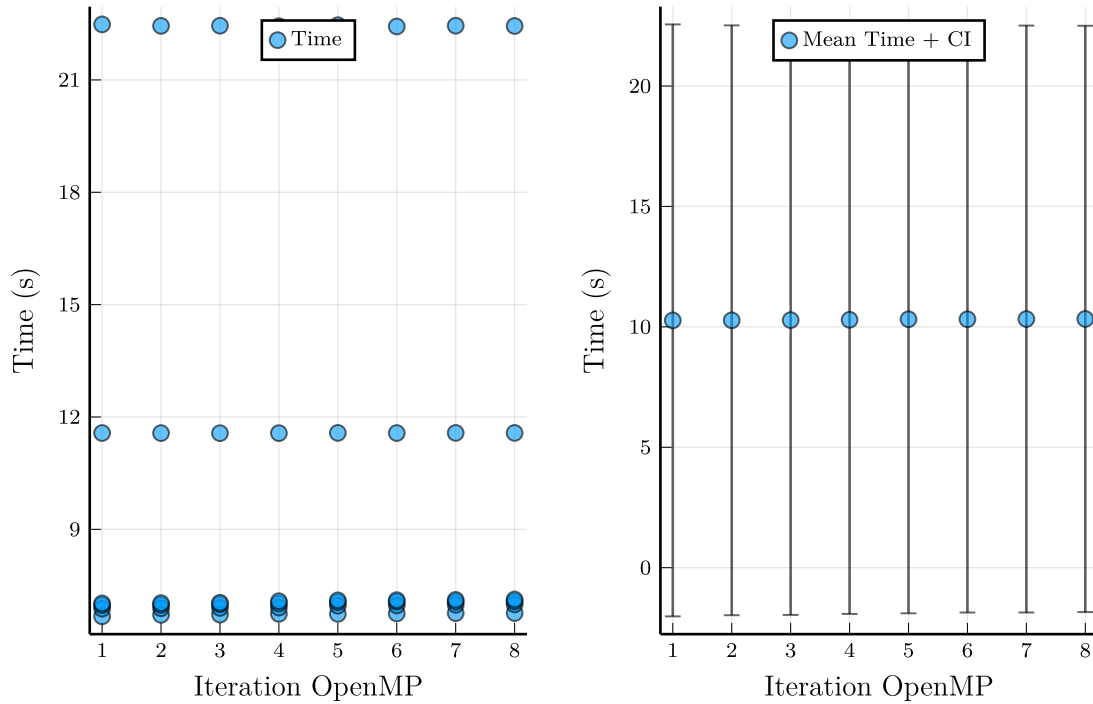
1.5.1 Tempo x Iterações

```

[15]: p1 = plot_results_iteration(omp_triple_spiral.iteration,
    omp_triple_spiral.time_elapsed,
    "Iteration OpenMP",
    "Time (s)",
    "Time",
    max_size_iteration = 8)
p2 = plot_results_iteration(parsed_iteration_omp_triple_spiral.iteration,
    parsed_iteration_omp_triple_spiral.mean_time,
    "Iteration OpenMP",
    "Time (s)",
    "Mean Time + CI",
    yerror = parsed_iteration_omp_triple_spiral.ci_time,
    max_size_iteration = 8)
plot(p1,p2)

```

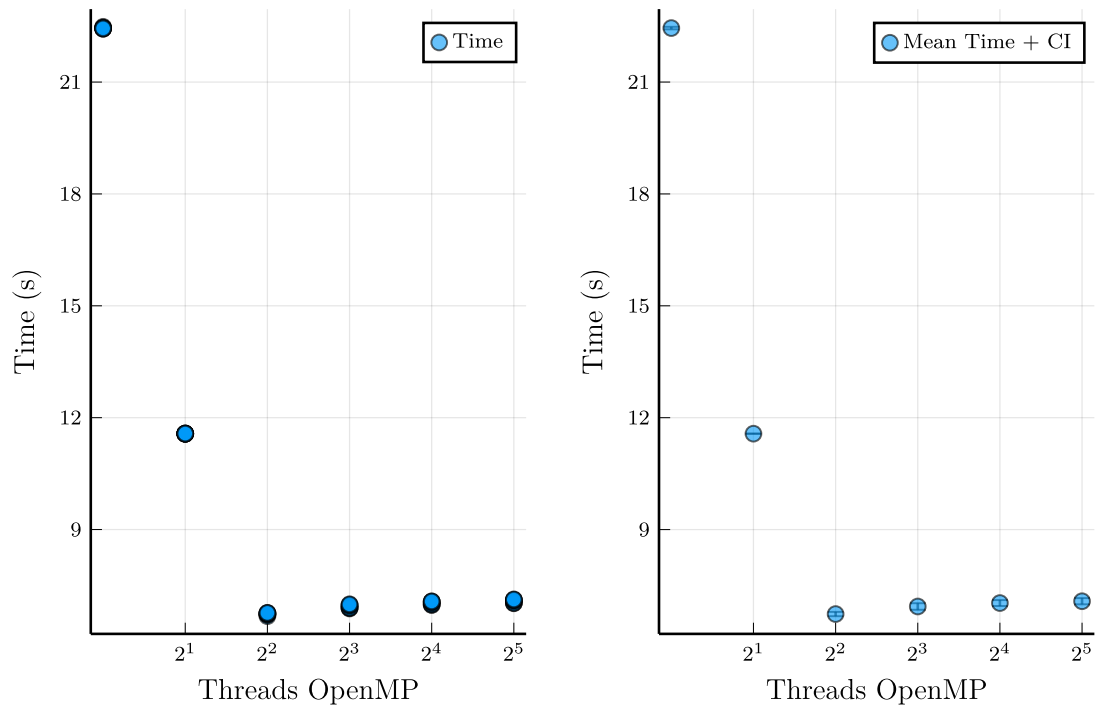
[15]:



1.5.2 Tempo x Threads

```
[16]: p1 = plot_results_thread(omp_triple_spiral.threads,
    omp_triple_spiral.time_elapsed,
    "Threads OpenMP",
    "Time (s)",
    "Time",
    max_thread_power = 5)
p2 = plot_results_thread(parsed_threads_omp_triple_spiral.threads,
    parsed_threads_omp_triple_spiral.mean_time,
    "Threads OpenMP",
    "Time (s)",
    "Mean Time + CI",
    yerror = parsed_threads_omp_triple_spiral.ci_time,
    max_thread_power = 5)
plot(p1,p2)
```

[16]:

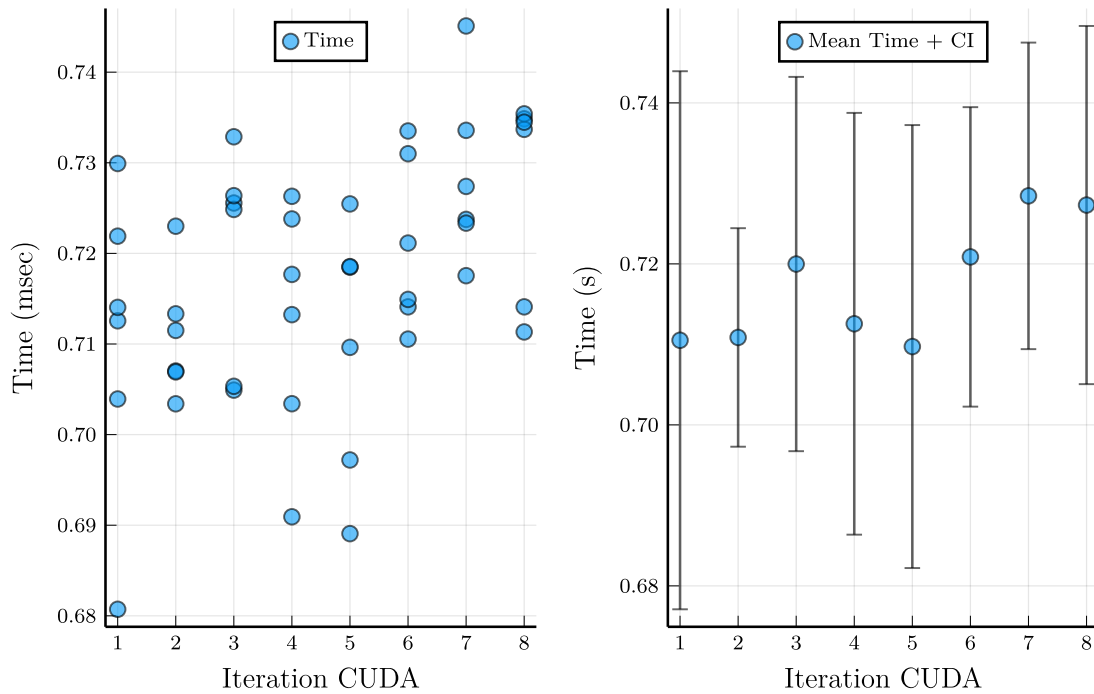


1.6 Gráficos CUDA

1.6.1 Tempo x Iterações

```
[17]: p1 = plot_results_iteration(cuda_triple_spiral.iteration,
    cuda_triple_spiral.time_elapsed,
    "Iteration CUDA",
    "Time (msec)",
    "Time",
    max_size_iteration = 8)
p2 = plot_results_iteration(parsed_iteration_cuda_triple_spiral.iteration,
    parsed_iteration_cuda_triple_spiral.mean_time,
    "Iteration CUDA",
    "Time (s)",
    "Mean Time + CI",
    yerror = parsed_iteration_cuda_triple_spiral.ci_time,
    max_size_iteration = 8)
plot(p1, p2)
```

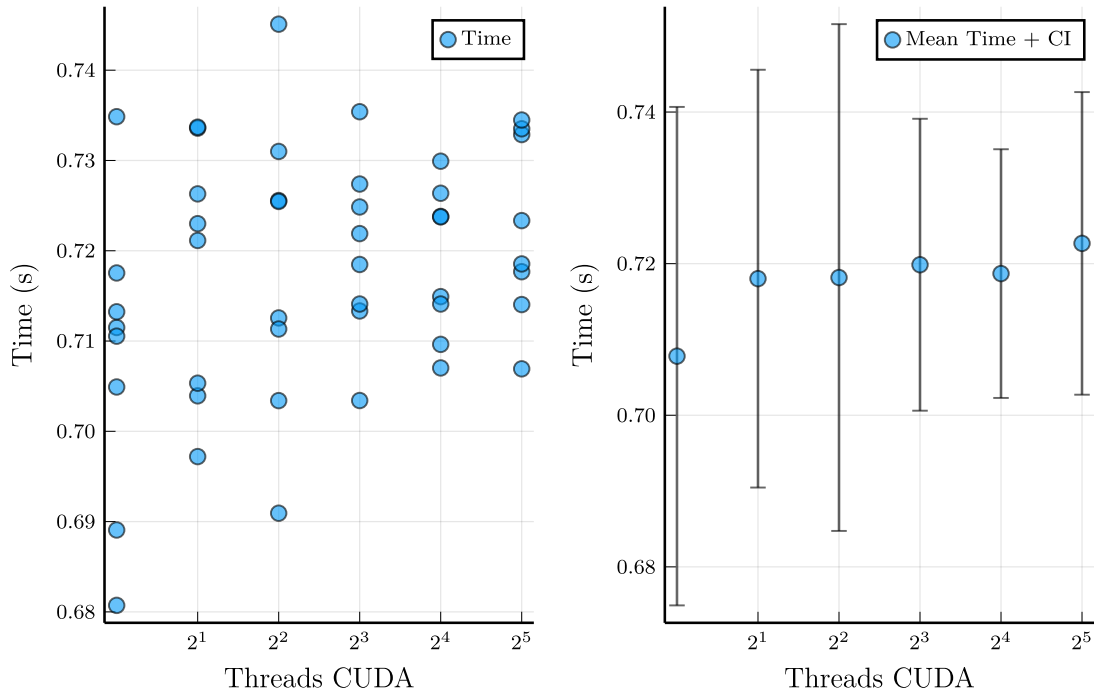
[17]:



1.6.2 Tempo x Threads

```
[18]: p1 = plot_results_thread(cuda_triple_spiral.threads,
    cuda_triple_spiral.time_elapsed,
    "Threads CUDA",
    "Time (s)",
    "Time",
    max_thread_power = 5)
p2 = plot_results_thread(parsed_threads_cuda_triple_spiral.threads,
    parsed_threads_cuda_triple_spiral.mean_time,
    "Threads CUDA",
    "Time (s)",
    "Mean Time + CI",
    yerror = parsed_threads_cuda_triple_spiral.ci_time,
    max_thread_power = 5)
plot(p1,p2)
```

[18]:

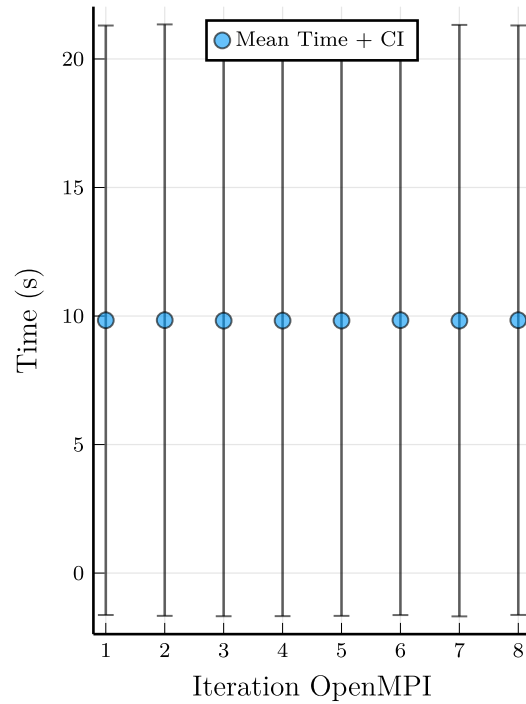
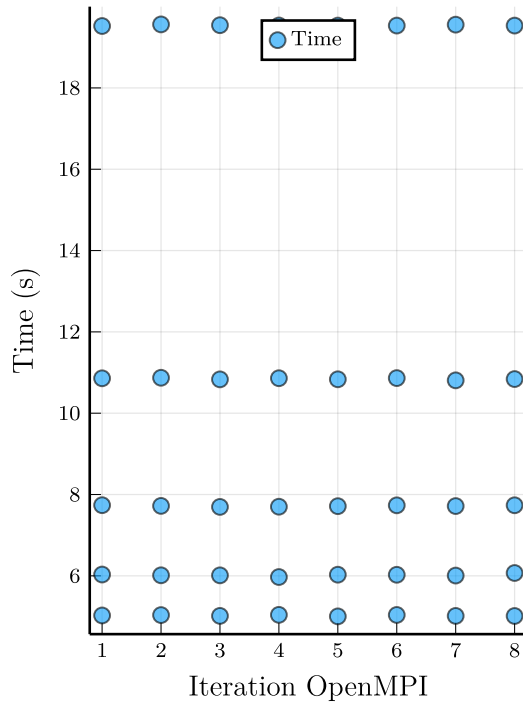


1.7 Gráficos OpenMPI

1.7.1 Tempo x Iterações

```
[19]: p1 = plot_results_iteration(ompi_triple_spiral.iteration,
    ompi_triple_spiral.time_elapsed,
    "Iteration OpenMPI",
    "Time (s)",
    "Time",
    max_size_iteration = 8)
p2 = plot_results_iteration(parsed_iteration_ompi_triple_spiral.iteration,
    parsed_iteration_ompi_triple_spiral.mean_time,
    "Iteration OpenMPI",
    "Time (s)",
    "Mean Time + CI",
    yerror = parsed_iteration_ompi_triple_spiral.ci_time,
    max_size_iteration = 8)
plot(p1,p2)
```

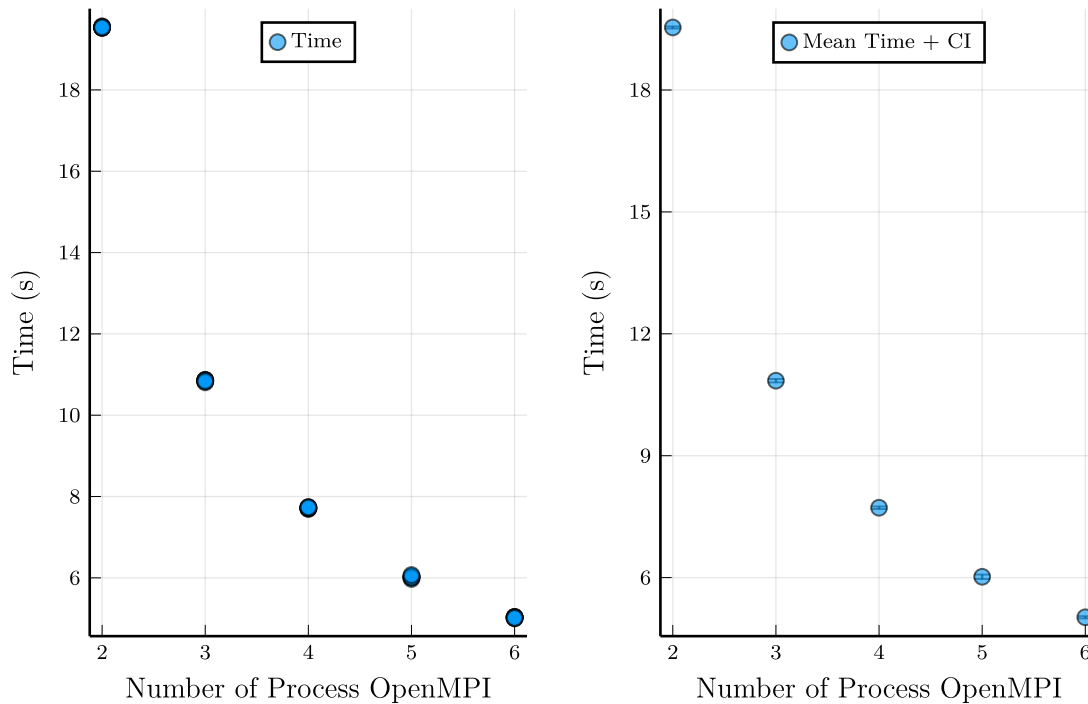
[19]:



1.7.2 Tempo x Threads

```
[20]: p1 = plot_results_iteration(ompi_triple_spiral.threads,
    ompi_triple_spiral.time_elapsed,
    "Number of Process OpenMPI",
    "Time (s)",
    "Time",
    max_size_iteration = 6)
p2 = plot_results_iteration(parsed_threads_ompi_triple_spiral.threads,
    parsed_threads_ompi_triple_spiral.mean_time,
    "Number of Process OpenMPI",
    "Time (s)",
    "Mean Time + CI",
    yerror = parsed_threads_ompi_triple_spiral.ci_time,
    max_size_iteration = 6)
plot(p1,p2)
```

[20]:



1.7.3 Análises

Iterações: Pelos gráficos apresentados nota-se que praticamente não há nenhuma diferença grande nos tempos de execução se repetir o código várias vezes, o CUDA é uma exceção, pois o seu intervalo no eixo y é mais preciso que os outros casos.

O grande intervalo de confiança apresentado nos gráficos de 'Tempo x Iterações', no caso do CUDA acontece como no caso anterior, pelo seu pequeno intervalo no eixo y, já nos outros casos ocorre, pois sempre há a execução com uma thread que executa com o mesmo tempo que o caso sequencial, o que causa um outlier em relação com os outros pontos que executam com mais threads.

Em relação ao tempo médio de execução, temos que o sequencial ainda é o mais lento com aproximadamente 22 segundos, e as versões com Pthreads, OpenMP e OpenMPI, possuem praticamente o mesmo tempo médio de aproximadamente 10 segundos e por último o que possui o tempo mais rápido entre todas as versões, o CUDA com cerca de 0.71 segundos de tempo de execução.

Numero de threads, Dimensões (x, y) do grid e dos blocos e Número de processos: Nos casos em que são utilizadas as threads como no OpenMP e no Pthreads, percebe-se que após a utilização de 4 threads o tempo se mantém constante, com um valor menor que 1, pois esse foi o limite máximo em que mais threads geram mais performance e passou a ter threads brigando por recursos não existentes atrasando o processamento.

No **OpenMPI** esse valor menor que 1, só foi alcançado com um número de processos igual a 6, pois (...)

No **CUDA** o tempo de execução sempre foi menor que 1, sendo que quando sua dimensão é igual a 1, ele apresentou tempos um pouco menores, sendo que com o restante das outras dimensões o tempo se manteve relativamente constante, isso ocorreu devido (...)

Em todos os casos a intervalo de confiança foi muito pequeno para ser considerado.