

# NPB\_statistics - Frederico

November 21, 2022

## 1 NPB Statistics

### 1.1 Utils

#### 1.1.1 Imports

```
[1]: import sys
import argparse
import math
import numpy as np
from scipy.stats import t
import scipy.stats as stats
import csv
import matplotlib.pyplot as plt
import matplotlib.ticker as ticker
```

```
[2]: from google.colab import drive
drive.mount('/content/drive')
```

Drive already mounted at /content/drive; to attempt to forcibly remount, call `drive.mount("/content/drive", force_remount=True)`.

#### 1.1.2 Global variables

```
[3]: ##Global variables
#VER_PYTHON_SERIAL="PYTHON-SERIAL"
#VER_CPP_SERIAL="CPP-SERIAL"
#VER_PYTHON_CUDA="PYTHON-CUDA"
#VER_CUDA="CPP-CUDA"
#VER_OPENACC="CPP-OPENACC"
#VER_RTM_INTEL="RTM-INTEL"
VER_RTM_INTEL_R1="RTM-INTEL-r1"
VER_RTM_INTEL_R50="RTM-INTEL-r50"
VER_RTM_INTEL_R500="RTM-INTEL-r500"
VER_STM_TINY="STM-TINY"
VER_STM_SWISS="STM-SWISS"
```

```

VER_SEQ="SEQ"

#VERSIONS_SERIAL = [VER_PYTHON_SERIAL, VER_CPP_SERIAL]
#VERSIONS_GPU = [VER_PYTHON_CUDA, VER_CUDA, VER_OPENACC]
#VERSIONS = [VER_HTM_INTEL, VER_STM_TINY]
#VERSIONS = [VER_RTM_INTEL, VER_SEQ]
VERSIONS = []
#fullVerList = [VER_RTM_INTEL, VER_STM_TINY, VER_STM_SWISS, VER_SEQ]
fullVerList = [VER_RTM_INTEL_R1, VER_RTM_INTEL_R50, VER_RTM_INTEL_R500,
↳VER_STM_TINY, VER_STM_SWISS, VER_SEQ]

#----Talvez trocar os nomes pra só "Lo" e "Hi" pra parar de ficar torto as
↳tabelas----
##CLASSES = ["B", "C"]
#CLASSES = ["LoContention", "HiContention"]
CLASSES = []
#fullClssList = ["LoContention", "HiContention"]
fullClssList = ["Low", "High"]

##BENCHS = ["BT", "CG", "EP", "FT", "IS", "LU", "MG", "SP"]
#BENCHS = ["bayes", "genome", "intruder", "kmeans", "labyrinth", "ssca2",
↳"vacation", "yada"]
#BENCHS = ["bayes", "genome", "kmeans", "labyrinth", "intruder", "yada"]
BENCHS = []
fullBnchList = ["bayes", "genome", "intruder", "kmeans", "labyrinth", "ssca2",
↳"vacation", "yada"]

#Para facilmente poder remover algum, listar os que devem ser ignorados da
↳lista criada com base no arquivo
#ignoreVer = [VER_RTM_INTEL, VER_STM_TINY]
#ignoreClss = ["LoContention"]
#ignoreBnch = ["bayes", "genome", "kmeans", "labyrinth", "ssca2", "vacation"]

ignoreVer = ["SEQ"]
ignoreClss = ["High"]
ignoreBnch = []

fileName = "/content/drive/MyDrive/Colab Notebooks/Arquivos/tratado"
with open(fileName) as f:
    file = f.read()
    if(("RTM-INTEL-r1" in file) and not("RTM-INTEL-r1" in ignoreVer)):
        VERSIONS.append(VER_RTM_INTEL_R1)
    if(("RTM-INTEL-r50" in file) and not("RTM-INTEL-r50" in ignoreVer)):
        VERSIONS.append(VER_RTM_INTEL_R50)
    if(("RTM-INTEL-r500" in file) and not("RTM-INTEL-r500" in ignoreVer)):
        VERSIONS.append(VER_RTM_INTEL_R500)
    if(("STM-TINY" in file) and not("STM-TINY" in ignoreVer)):

```

```

VERSIONS.append(VER_STM_TINY)
if(("STM-SWISS" in file) and not("STM-SWISS" in ignoreVer)):
    VERSIONS.append(VER_STM_SWISS)
if(("SEQ" in file) and not("SEQ" in ignoreVer)):
    VERSIONS.append(VER_SEQ)

#for cls in fullClsList:
#    if((cls in file) and not(cls in ignoreCls)):
#        CLASSES.append(cls)
for cls in fullClsList:
    if((cls in file) and not(cls in ignoreCls)):
        CLASSES.append(cls)

for Bnch in fullBnchList:
    if((Bnch in file) and not(Bnch in ignoreBnch)):
        BENCHS.append(Bnch)

dic_dados = {}
dic_dados_bench = {}
g_bench = ""

```

### 1.1.3 Statistical methods

```

[4]: # CSV
def le_csv_desempenho(arquivos, prefixo, array_dados):
    if len(arquivos) < 1:
        return
    for a in arquivos:
        with open(a) as f:
            reader = csv.reader(f, delimiter=';', quoting=csv.
→QUOTE_NONE)
            filtro = list(filter(lambda x: len(x) > 0 and x[0] ==
→prefixo, reader))

            for linha in filtro:
                array_dados.append(linha[1:])
#END

def split(dado):
    aux = dado.split("=")
    if len(aux) == 2:
        return aux[1]
    return dado
#END

# DICTIONARY

```

```

def name_versao(versao):
    if "RTM" in versao:
        if "INTEL" in versao:
            if "r500" in versao:
                return "RTM-500"
            if "r50" in versao:
                return "RTM-50"
            if "r1" in versao:
                return "RTM-1"
        elif "IBM" in versao:
            return "IBM"
    elif "STM" in versao:
        if "TINY" in versao:
            return "TinySTM"
        elif "SWISS" in versao:
            return "SwissTM"
    elif "SEQ" in versao:
        return "Sequential"

    #if "PYTHON" in versao:
    #     if "SERIAL" in versao:
    #         return "Python"
    #     elif "CUDA" in versao:
    #         return "Numba"
    #elif "OPENACC" in versao:
    #     return "OpenACC"
    #elif "CPP" in versao:
    #     if "SERIAL" in versao:
    #         return "C++"
    #     elif "CUDA" in versao:
    #         return "Cuda"

    return ""

#END

def idx_dicionario(versao, classe):
    return versao + "$$" + classe

##Classe, size e gpus acho que não é necessário
def add_dicionario(dic, idx, desc, classe, size, interaction, cpus, gpus, times):
    dic[idx] = {}
    dic[idx]["desc"] = desc
    dic[idx]["class"] = classe
    dic[idx]["size"] = size
    dic[idx]["interaction"] = interaction
    dic[idx]["cpus"] = cpus
    dic[idx]["gpus"] = gpus

```

```

        dic[idx]["times"] = times
#END

#Statistics
def calc_stats(amostra):
    # confidence interval of 95%
    tdist = t.ppf(0.95, len(amostra)-1)
    mean = np.mean(amostra)
    std = np.std(amostra)
    error = tdist*(std/math.sqrt(len(amostra)))
    return mean, std, error

def report_df(data):
    mean, std, error = calc_stats(data)
    data_sort = sorted(data)
    sz = len(data)

    ks_stat, ks_p, ks_p_ok = ks_gaussian_test(data)
    sw_stat, sw_p, sw_p_ok = shapiro_wilk_gaussian_test(data)

    print("%12s %15.8f" %("count", sz))
    print("%12s %15.8f" %("mean", mean))
    print("%12s %15.8f" %("std", std))
    print("%12s %15.8f" %("error (95%)", error))
    print("%12s %15.8f" %("min", min(data)))
    print("%12s %15.8f" %("25%", max(data_sort[: (int(sz*0.25) if int(sz*0.
→25) > 1 else 1)])) ) )
    print("%12s %15.8f" %("50%", max(data_sort[:int(sz*0.50)])) ) )
    print("%12s %15.8f" %("75%", max(data_sort[:int(sz*0.75)])) ) )
    print("%12s %15.8f" %("max", max(data)))
    print("%12s %15.8f" %("KS stat", ks_stat))
    print("%12s %15.8f" %("KS p", ks_p))
    print("%12s %15s" %("KS p>0.05", "Sample OK" if ks_p_ok else "Sample_
→Bad")) )
    print("%12s %15.8f" %("SW stat", sw_stat))
    print("%12s %15.8f" %("SW p", sw_p))
    print("%12s %15s" %("SW p>0.05", "Sample OK" if sw_p_ok else "Sample_
→Bad")) )
#END

def report_df_all(dic):
    column_0 = ["count", "mean", "std", "error (95%)", "min", "25%", "50%",
→"75%", "max",
                "KS stat", "KS p", "KS p>0.05", "SW stat", "SW_
→p", "SW p>0.05"]

    rows = []

```

```

rows.append([])
i = 0
for c in column_0:
    rows[i].append("%12s" % (c))
    rows.append([])
    i += 1

header = []
header.append("%12s" % (""))
for idx, dados in dic.items():
    header.append("%15s" % (dados["desc"] + " - " + dados["class"]))

    data = dados["times"]
    mean, std, error = calc_stats(data)
    data_sort = sorted(data)
    sz = len(data)

    ks_stat, ks_p, ks_p_ok = ks_gaussian_test(data)
    sw_stat, sw_p, sw_p_ok = shapiro_wilk_gaussian_test(data)

    rows[0].append("%15.8f" %(sz))
    rows[1].append("%15.8f" %(mean))
    rows[2].append("%15.8f" %(std))
    rows[3].append("%15.8f" %(error))
    rows[4].append("%15.8f" %(min(data)))
    rows[5].append("%15.8f" %(max(data_sort[: (int(sz*0.25) if
↪int(sz*0.25) > 1 else 1)]))))
    rows[6].append("%15.8f" %(max(data_sort[:int(sz*0.50)])))
    rows[7].append("%15.8f" %(max(data_sort[:int(sz*0.75)])))
    rows[8].append("%15.8f" %(max(data)))
    rows[9].append("%15.8f" %(ks_stat))
    rows[10].append("%15.8f" %(ks_p))
    rows[11].append("%15s" %( ("Sample OK" if ks_p_ok else "Sample_
↪Bad") ))
    rows[12].append("%15.8f" %(sw_stat))
    rows[13].append("%15.8f" %(sw_p))
    rows[14].append("%15s" %( ("Sample OK" if sw_p_ok else "Sample_
↪Bad") ))

for i in range(len(column_0)):
    if i == 0:
        print(header[0], end="")
        j = 1
        for idx in dic.items():
            print(header[j], end="")
            j += 1
        print()

```

```

        j = 0
        for idx, dados in dic.items():
            if j == 0:
                print(rows[i][j], end="")
                j += 1

            print(rows[i][j], end="")
            j += 1
        print()
#END

def ks_gaussian_test(data):
    loc, scale = stats.norm.fit(data)
    n = stats.norm(loc=loc, scale=scale)

    stat, p = stats.kstest(data, n.cdf)

    alpha = 0.05
    return stat, p, (p > alpha)
#END

def ks_gaussian_test_chart(data):
    loc, scale = stats.norm.fit(data)
    n = stats.norm(loc=loc, scale=scale)

    plt.hist(data, rwidth=0.5)
    #x = numpy.arange(min(data), max(data) + 0.2, 0.02)
    #plt.plot(x, data.mean()*n.pdf(x))
    plt.title('Comparação Entre Histograma e Projeção da Distribuição ↵
↪Normal')
    plt.title('Histograma da Distribuição')
    plt.xlabel('Tempo de Execução')
    plt.ylabel('Número de Ocorrências')

    plt.show()

    stat, p = stats.kstest(data, n.cdf)
    print('Statistics=%.5f, p=%.5f' % (stat, p))

    alpha = 0.05
    if p > alpha:
        print('Sample looks Gaussian (fail to reject H0)')
    else:
        print('Sample does not look Gaussian (reject H0)')
#END

```

```

def shapiro_wilk_gaussian_test(data):
    stat, p = stats.shapiro(data)

    alpha = 0.05
    return stat, p, (p > alpha)
#END

# generate boxplot containing all columns from two dataframes (side by side,
→ comparison)
def boxplot_chart(data, version):
    data_set = [data]
    fig, ax = plt.subplots()

    #Plot boxplot
    bp = ax.boxplot(data_set, widths=0.25, patch_artist = True)

    # changing color and linewidth of whiskers
    for whisker in bp['whiskers']:
        whisker.set(color = '#8B008B', linewidth = 1.5, linestyle = ":")

    # changing color and linewidth of caps
    for cap in bp['caps']:
        cap.set(color = '#8B008B', linewidth = 2)

    # changing color and linewidth of medians
    for median in bp['medians']:
        median.set(color = 'red', linewidth = 3)

    # changing style of fliers
    for flier in bp['fliers']:
        flier.set(marker = 'D', color = '#e7298a', alpha = 0.5)

    # changing color
    colors = ['#0000FF', '#00FF00', '#FFFF00', '#FF00FF'] #Support for 4
→ series
    for patch, color in zip(bp['boxes'], colors):
        patch.set_facecolor(color)

    plt.xticks([1], [version])
    plt.ylabel('Execution time (s)')

    fig.tight_layout()
    plt.show()
#END

```



```

# apply student t test comparing two statistics
# Null Hypothesis (H0):  $\mu_a = \mu_b$  (the means of both populations are equal)
# Alternate Hypothesis (Ha):  $\mu_a \neq \mu_b$  (the means of both populations are not
    ↪ equal)
def student_t_test(pop_a, pop_b):
    t_stat, p_value = stats.ttest_ind(pop_a, pop_b, equal_var=False)
    return t_stat, p_value, (p_value <= 0.05)
#END

def student_t_test_report(pop_a, pop_b):
    t_stat, p_value, p_value_ok = student_t_test(pop_a, pop_b)

    print("P-Value={0} T-Statistic={1}".format(p_value, t_stat))

    #if p_value <= 0.05:
    if p_value_ok:
        print('The mean of the samples is different (reject H0)')
    else:
        print('The mean of the samples is equal (fail to reject H0)')
#END

def mann_whitney_u_test(pop_a, pop_b):
    t_stat, p_value = stats.mannwhitneyu(pop_a, pop_b,
    ↪ use_continuity=False, alternative='two-sided')
    return t_stat, p_value, (p_value <= 0.05)
#END

def mann_whitney_u_test_report(pop_a, pop_b):
    t_stat, p_value, p_value_ok = mann_whitney_u_test(pop_a, pop_b)

    print("P-Value={0} T-Statistic={1}".format(p_value, t_stat))

    #if p_value <= 0.05:
    if p_value_ok:
        print('The mean of the samples is different (reject H0)')
    else:
        print('The mean of the samples is equal (fail to reject H0)')
#END

def t_u_tests_report_all(dic, versions): #Versions is a matrix [[v1, v2], [v2,
    ↪ v3]...]
    column_0 = ["KS OK?", "T-Test p", "T-Test stat", "T-Test p<=0.05",
        "U-Test p", "U-Test stat",
    ↪ "U-Test p<=0.05"]

    rows = []
    rows.append([])

```

```

i = 0
for c in column_0:
    rows[i].append("%15s" % (c))
    rows.append([])
    i += 1

header = []
header.append("%15s" % (""))
for v in versions:
    dic_a = dic[v[0]]
    pop_a = dic_a["times"]

    dic_b = dic[v[1]]
    pop_b = dic_b["times"]

    head = "(" + dic_a["desc"] + "[" + dic_a["class"] + ") x (" +
    ↪dic_b["desc"] + "[" + dic_b["class"] + ")")
    header.append("%27s" % (head))

    a_ks_stat, a_ks_p, a_ks_p_ok = ks_gaussian_test(pop_a)
    b_ks_stat, b_ks_p, b_ks_p_ok = ks_gaussian_test(pop_b)
    ks_ok = (a_ks_p_ok and b_ks_p_ok)

    t_stat, t_p_value, t_p_value_ok = student_t_test(pop_a, pop_b)

    u_stat, u_p_value, u_p_value_ok = mann_whitney_u_test(pop_a,
    ↪pop_b)

    rows[0].append("%27s" % ( ("Yes" if ks_ok else "No") ))
    rows[1].append("%27.12e" % (t_p_value))
    rows[2].append("%27.8f" % (t_stat))
    t_test_app = ("T-Test OK" if t_p_value_ok else "T-Test Failed")
    ↪if ks_ok else "Not normally distrib."
    rows[3].append("%27s" % ( t_test_app ))
    rows[4].append("%27.12e" % (u_p_value))
    rows[5].append("%27.8f" % (u_stat))
    rows[6].append("%27s" % ( ("U-Test OK" if u_p_value_ok else
    ↪"U-Test Failed") ))

    for i in range(len(column_0)):
        if i == 0:
            print(header[0], end="")
            for j in range(1, len(versions)+1):
                print(header[j], end="")
            print()

```

```

        for j in range(0, len(versions)+1):
            print(rows[i][j], end="")

        print()

#END

```

#### 1.1.4 Load dictionary

```

[5]: def load_data_dictionary(bench):
    global g_bench
    g_bench = bench

    # Load dictionary
    dados = [] # array das linhas

    #le_csv_desempenho(["sample_data/exec_20220224_BT.txt", "sample_data/
    ↪exec_20210924_EP.txt",
    #
    ↪"sample_data/exec_20210929_CG.txt", "sample_data/
    ↪exec_20210930_FT.txt",
    #
    ↪"sample_data/exec_20211001_MG.txt", "sample_data/
    ↪exec_20220227_LU.txt",
    #
    ↪"sample_data/exec_20211001_IS.txt", "sample_data/
    ↪exec_20220226_SP.txt"], "BENCH=" + bench, dados)
    #le_csv_desempenho(["/content/sample_data/exec_20210924_EP.txt"], "BENCH=" +
    ↪bench, dados)
    #le_csv_desempenho(["/content/sample_data/tratado"], "BENCH=" + bench,
    ↪dados)

    le_csv_desempenho(["/content/drive/MyDrive/Colab Notebooks/Arquivos/
    ↪tratado"], "BENCH=" + bench, dados)

    bench_process_data(dados, bench)

```

#### 1.1.5 Benchmark Methods

```

[6]: def bench_time_chart():
    times = []
    class_ids = range(1, len(CLASSES)+2, 2)

    max_time = 0
    #for v in VERSIONS_GPU:
    for v in VERSIONS:
        #if g_bench == "IS" and "OPENACC" in v:
        #
        ↪continue

```

```

        v_time = []

        #time, a, b = calc_stats(dic_dados[idx_dicionario(v,
↪ "LoContention"))["times"])
        time, a, b = calc_stats(dic_dados[idx_dicionario(v,
↪ "Low"))["times"])
        v_time.append(time)
        max_time = max(time, max_time)

        #if "HiContention" in CLASSES:
        if "High" in CLASSES:
            #time, a, b = calc_stats(dic_dados[idx_dicionario(v,
↪ "HiContention"))["times"])
            time, a, b = calc_stats(dic_dados[idx_dicionario(v,
↪ "High"))["times"])
            v_time.append(time)
            max_time = max(time, max_time)

        times.append(v_time)

    #Chart
    #desenha as barras no gráfico
    fig, ax = plt.subplots()

    bars = []
    #idx = -0.3
    idx = (1.5/len(times))
    value = idx * -(math.floor(len(times)/2))
    for t in times:
        bar = ax.bar(np.array(class_ids)+value, np.array(t), width=0.25)
        bars.append(bar)
        value += idx

    ax.set_xlabel('Classes')
    ax.set_ylabel('Execution time (s)')
    ax.set_xlim(0, 4)
    ax.set_ylim(0, math.ceil(max_time))

    #ax.title('Execution time')
    ax.legend(tuple(map(name_versao, VERSIONS)))

    ax.set_xticks(class_ids)
    ax.set_xticklabels(CLASSES)

    #for b in bars:
    #    ax.bar_label(b, padding=3, fmt='%5.3f')

```

```

fig.tight_layout()

plt.show() #mostra o gráfico
#END

def bench_speedup_chart(version_serial, versions_gpu):
    speedups = []
    class_ids = range(1, len(CLASSES)+2, 2)
    #class_ids = range((4/len(CLASSES)), (4/len(CLASSES))*2)

    #time_serial_B, a, b =
    ↪ calc_stats(dic_dados[idx_dicionario(version_serial, "B")]["times"])
    #time_serial_C, a, b =
    ↪ calc_stats(dic_dados[idx_dicionario(version_serial, "C")]["times"])
    #if "LoContention" in CLASSES:
    #     time_serial_Lo, a, b =
    ↪ calc_stats(dic_dados[idx_dicionario(version_serial,
    ↪ "LoContention")]["times"])
    #if "HiContention" in CLASSES:
    #     time_serial_Hi, a, b =
    ↪ calc_stats(dic_dados[idx_dicionario(version_serial,
    ↪ "HiContention")]["times"])
    if "Low" in CLASSES:
        time_serial_Lo, a, b =
    ↪ calc_stats(dic_dados[idx_dicionario(version_serial, "Low")]["times"])
    if "High" in CLASSES:
        time_serial_Hi, a, b =
    ↪ calc_stats(dic_dados[idx_dicionario(version_serial, "High")]["times"])

    max_speedup = 0
    for v in versions_gpu:
        v_speedup = []

        #if "LoContention" in CLASSES:
        #     time, a, b = calc_stats(dic_dados[idx_dicionario(v,
    ↪ "LoContention")]["times"])
        if "Low" in CLASSES:
            time, a, b = calc_stats(dic_dados[idx_dicionario(v,
    ↪ "Low")]["times"])

            speedup = time_serial_Lo/time
            v_speedup.append(speedup)
            max_speedup = max(speedup, max_speedup)

        #if "HiContention" in CLASSES:

```

```

        #         time, a, b = calc_stats(dic_dados[idx_dicionario(v, u
↪ "HiContention")]["times"])
        if "High" in CLASSES:
            time, a, b = calc_stats(dic_dados[idx_dicionario(v, u
↪ "High")]["times"])

            speedup = time_serial_Hi/time
            v_speedup.append(speedup)
            max_speedup = max(speedup, max_speedup)

    speedups.append(v_speedup)

#Chart
#desenha as barras no gráfico
fig, ax = plt.subplots()

bars = []
#idx = 0.30 if len(speedups) > 1 else 0.0
idx = 1.5/len(speedups) if len(speedups) > 1 else 0.0
value = idx * -(math.floor(len(speedups)/2))
for s in speedups:
    bar = ax.bar(np.array(class_ids)+value, np.array(s), width=0.25)
    bars.append(bar)
    value += idx

ax.set_xlabel('Classes')
ax.set_ylabel('Speedup')
ax.set_xlim(0, 4)
ax.set_ylim(0, math.ceil(max_speedup*1.1))

#ax.title('Speedup')
ax.legend(tuple(map(name_versao, versions_gpu)))

ax.set_xticks(class_ids)
ax.set_xticklabels(CLASSES)

#for b in bars:
#    ax.bar_label(b, padding=3)

fig.tight_layout()

plt.show() #mostra o gráfico
#END

def bench_report_t_u_tests(classe):
    versoes_comp = []

```

```

        #versoes_comp.append([idx_dicionario(VER_PYTHON_SERIAL, classe),
→idx_dicionario(VER_PYTHON_CUDA, classe)])
        #versoes_comp.append([idx_dicionario(VER_RTM_INTEL, classe),
→idx_dicionario(VER_SEQ, classe)])

        #versoes_comp.append([idx_dicionario(VER_RTM_INTEL, classe),
→idx_dicionario(VER_STM_TINY, classe)])
        #versoes_comp.append([idx_dicionario(VERSIONS[0], classe),
→idx_dicionario(VERSIONS[1], classe)])
        #versoes_comp.append(idx_dicionario(v, classe))
        for v in range(0, len(VERSIONS)-1):
            for v2 in range(v+1, len(VERSIONS)):
                versoes_comp.append([idx_dicionario(VERSIONS[v],
→classe), idx_dicionario(VERSIONS[v2], classe)])
                t_u_tests_report_all(dic_dados, versoes_comp)
                versoes_comp = []

        #versoes_comp.append([idx_dicionario(VER_CPP_SERIAL, classe),
→idx_dicionario(VER_CUDA, classe)])
        #if g_bench != "IS":
            #        versoes_comp.append([idx_dicionario(VER_CPP_SERIAL, classe),
→idx_dicionario(VER_OPENACC, classe)])
            #        versoes_comp.append([idx_dicionario(VER_CUDA, classe),
→idx_dicionario(VER_OPENACC, classe)])
            #versoes_comp.append([idx_dicionario(VER_PYTHON_CUDA, classe),
→idx_dicionario(VER_CUDA, classe)])
            #if g_bench != "IS":
                #        versoes_comp.append([idx_dicionario(VER_PYTHON_CUDA, classe),
→idx_dicionario(VER_OPENACC, classe)])

        #print(versoes_comp)
        #print(dic_dados)
        #t_u_tests_report_all(dic_dados, versoes_comp)
#END

def bench_calc_stats(dados, versao, classe, threads=0, gpus=0):
    global dic_dados

    idx_versao = 0
    idx_classe = 1
    idx_size = 2
    idx_iter = 3
    idx_threads = 4
    idx_gpus = 5
    idx_time = 6

```

```

        linhas = list(filter(lambda x: versao in split(x[idx_versao]) and
↪ classe in split(x[idx_classe]), dados))

        if len(linhas) > 0:
            times = [float(split(l[idx_time])) for l in linhas]
            add_dicionario(dic_dados, idx_dicionario(versao, classe),
↪ name_versao(versao), classe,
#                               split(linhas[0][idx_size]),
↪ split(linhas[0][idx_iter]), threads, gpus, times)
                               split(linhas[0][idx_size]),
↪ split(linhas[0][idx_iter]), split(linhas[0][idx_threads]), gpus, times)
#END

def bench_process_data(dados, bench):
    print("Gerando", bench, "...")

    for c in CLASSES:
        for v in VERSIONS:
            bench_calc_stats(dados, v, c, 1, 0)

            #for v in VERSIONS_GPU:
            #    if bench == "IS" and "OPENACC" in v:
            #        continue
            #    bench_calc_stats(dados, v, c, 0, 1)

    print(bench, "OK")
#END

def bench_apply_ks_tests(classe):
    for idx, value in dic_dados.items():
        if value["class"] == classe:
            print('-----', value["desc"], "-", value["class"],
↪ '-----')
            ks_gaussian_teste_chart(value["times"])
            print()
#END

def bench_apply_boxplots(classe):
    for idx, value in dic_dados.items():
        if value["class"] == classe:
            print('-----', value["desc"], "-", value["class"],
↪ '-----')
            boxplot_chart(value["times"], value["desc"] + " - " +
↪ value["class"])
            print()
#END

```



## 1.2 Main Benchmark

```
[7]: ##Parameter: BT | CG | EP | FT | IS | LU | MG | SP
    ##load_data_dictionary("EP")

    for b in BENCHS:
        load_data_dictionary(b)
```

```
Gerando bayes ...
bayes OK
Gerando genome ...
genome OK
Gerando intruder ...
intruder OK
Gerando kmeans ...
kmeans OK
Gerando labyrinth ...
labyrinth OK
Gerando ssca2 ...
ssca2 OK
Gerando vacation ...
vacation OK
Gerando yada ...
yada OK
```

### 1.2.1 Report DF

```
[8]: report_df_all(dic_dados)
```

	RTM-1 - Low	RTM-50 - Low	RTM-500 - Low	TinySTM - Low
SwissTM - Low	RTM-1 - High	RTM-50 - High	RTM-500 - High	TinySTM - High
SwissTM - High				
count	30.00000000	37.00000000	7.00000000	30.00000000
30.00000000	30.00000000	37.00000000	7.00000000	30.00000000
30.00000000				
mean	0.15813333	0.71324324	2.23342857	0.09640000
0.10370000	8.06883460	50.74735327	166.43853400	17.55868447
17.34454050				
std	0.00084591	0.73444623	0.00955969	0.00055377
0.00069041	0.07509578	56.02583192	9.10472888	0.12975196
0.15426650				
error (95%)	0.00026241	0.20384881	0.00702115	0.00017179
0.00021418	0.02329597	15.55021806	6.68699645	0.04025123
0.04785605				
min	0.15700000	0.35300000	2.22200000	0.09600000
0.10300000	7.97327700	23.36720200	162.08470700	17.38628100
17.14186900				

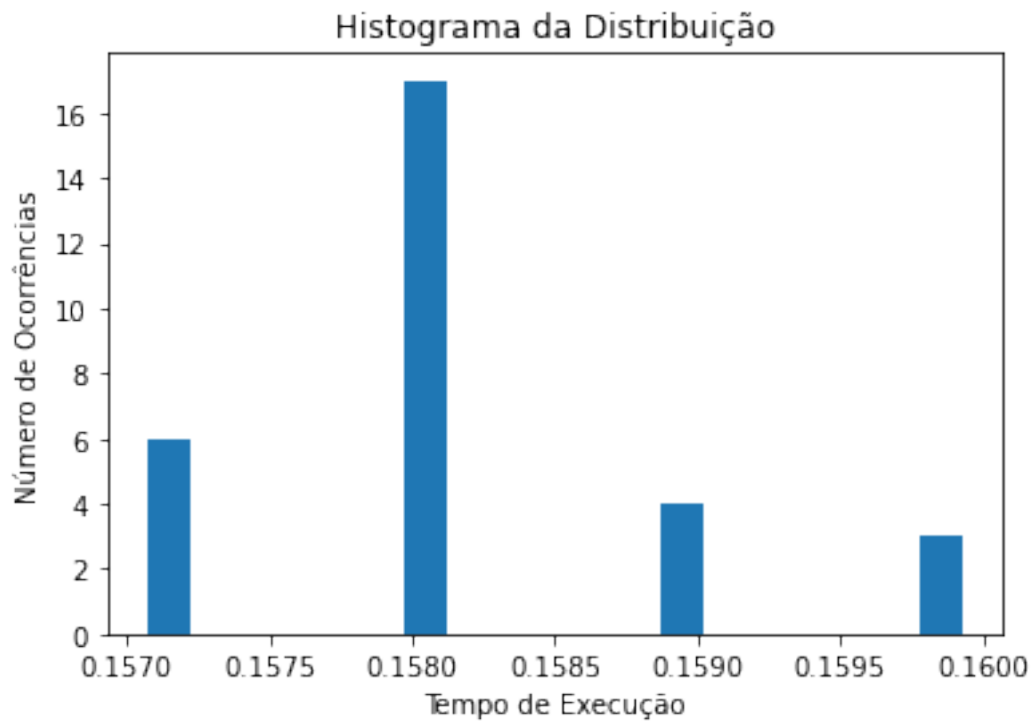
25%	0.15800000	0.35500000	2.22200000	0.09600000
0.10300000	8.01037900	23.54291700	162.08470700	17.44124400
17.21117700				
50%	0.15800000	0.35700000	2.22800000	0.09600000
0.10400000	8.02558100	23.64089700	162.52476300	17.52216600
17.32612800				
75%	0.15800000	0.35700000	2.23400000	0.09700000
0.10400000	8.10682000	24.27746600	163.16261100	17.60505800
17.38662600				
max	0.16000000	2.25300000	2.25300000	0.09800000
0.10500000	8.21485600	188.70525100	188.70525100	17.82436600
17.81947600				
KS stat	0.32928937	0.46948033	0.21149960	0.39828295
0.27801561	0.21768535	0.48627767	0.47456225	0.19473709
0.14981348				
KS p	0.00212453	0.00000005	0.85448764	0.00008335
0.01528637	0.09966094	0.00000001	0.05733030	0.17978156
0.46643610				
KS p>0.05	Sample Bad	Sample Bad	Sample OK	Sample Bad
Sample Bad	Sample OK	Sample Bad	Sample OK	Sample OK
Sample OK				
SW stat	0.81561947	0.48656350	0.90809351	0.66927099
0.78072971	0.85799658	0.49827093	0.50430793	0.89850789
0.91609687				
SW p	0.00012799	0.00000000	0.38283044	0.00000057
0.00002978	0.00091592	0.00000000	0.00001871	0.00772318
0.02126906				
SW p>0.05	Sample Bad	Sample Bad	Sample OK	Sample Bad
Sample Bad	Sample Bad	Sample Bad	Sample Bad	Sample Bad
Sample Bad				

## 1.2.2 KS Test

### Low Contention

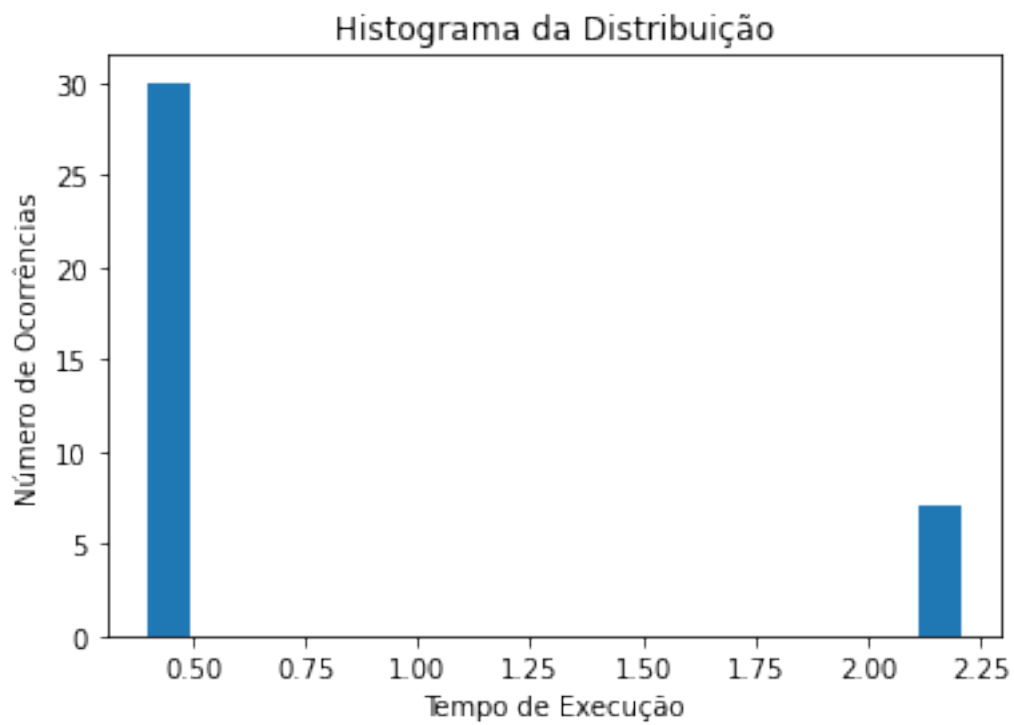
```
[9]: #bench_apply_ks_tests("B")
#bench_apply_ks_tests("LoContention")
bench_apply_ks_tests("Low")
```

----- RTM-1 - Low -----



Statistics=0.32929, p=0.00212  
Sample does not look Gaussian (reject H0)

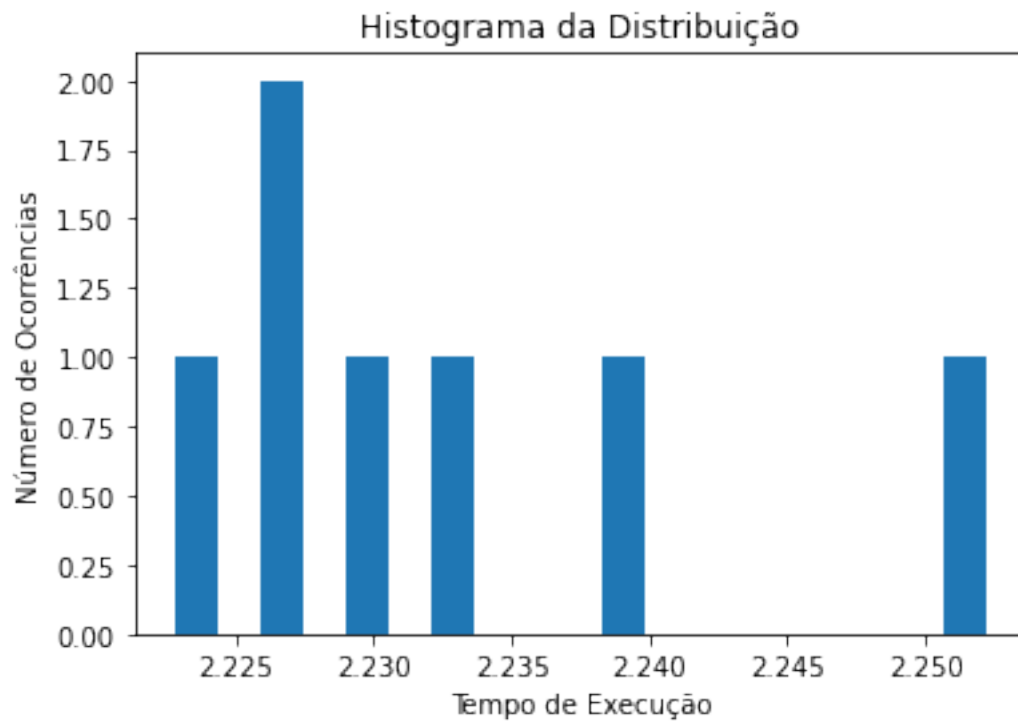
----- RTM-50 - Low -----



Statistics=0.46948, p=0.00000

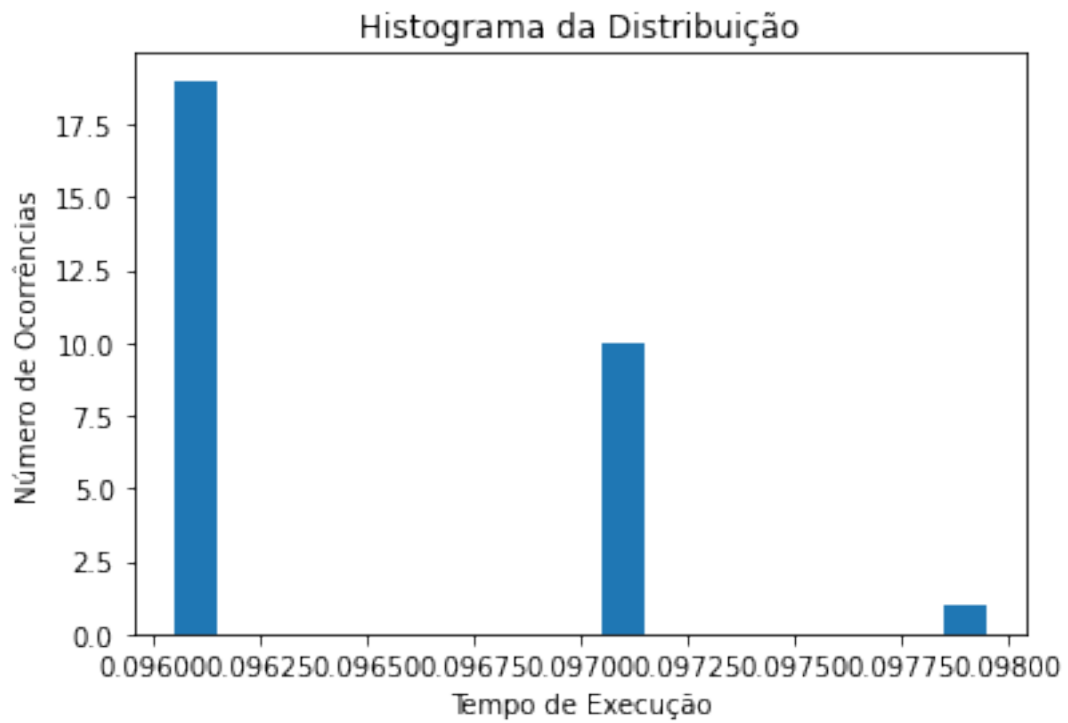
Sample does not look Gaussian (reject H0)

----- RTM-500 - Low -----



Statistics=0.21150, p=0.85449  
Sample looks Gaussian (fail to reject H0)

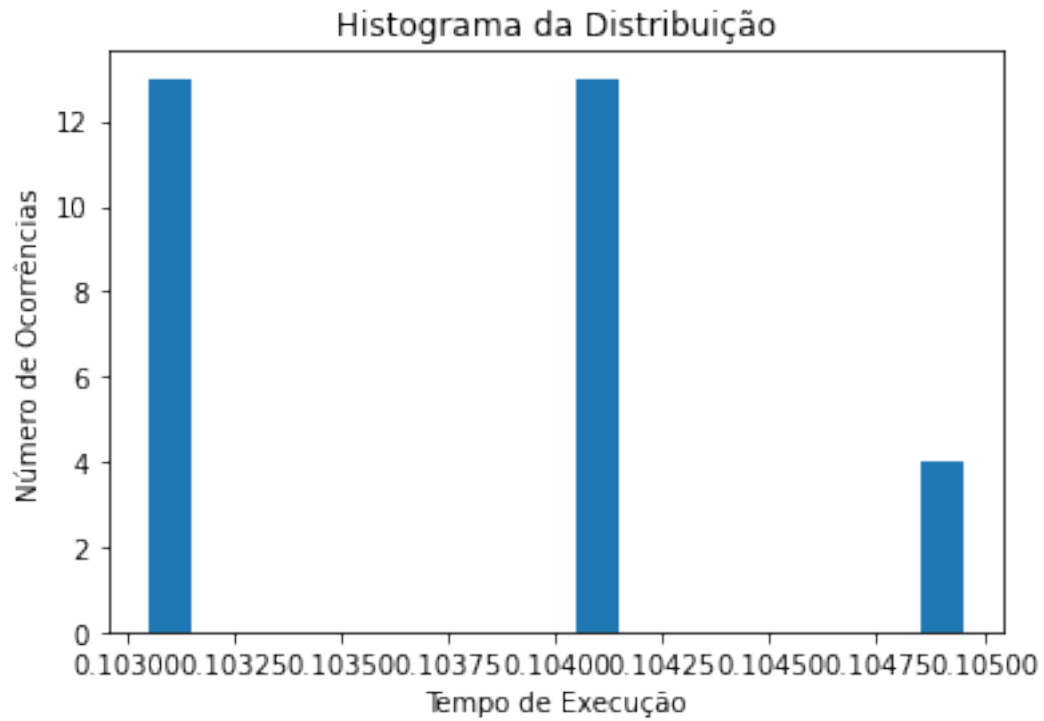
----- TinySTM - Low -----



Statistics=0.39828, p=0.00008

Sample does not look Gaussian (reject H0)

----- SwissTM - Low -----

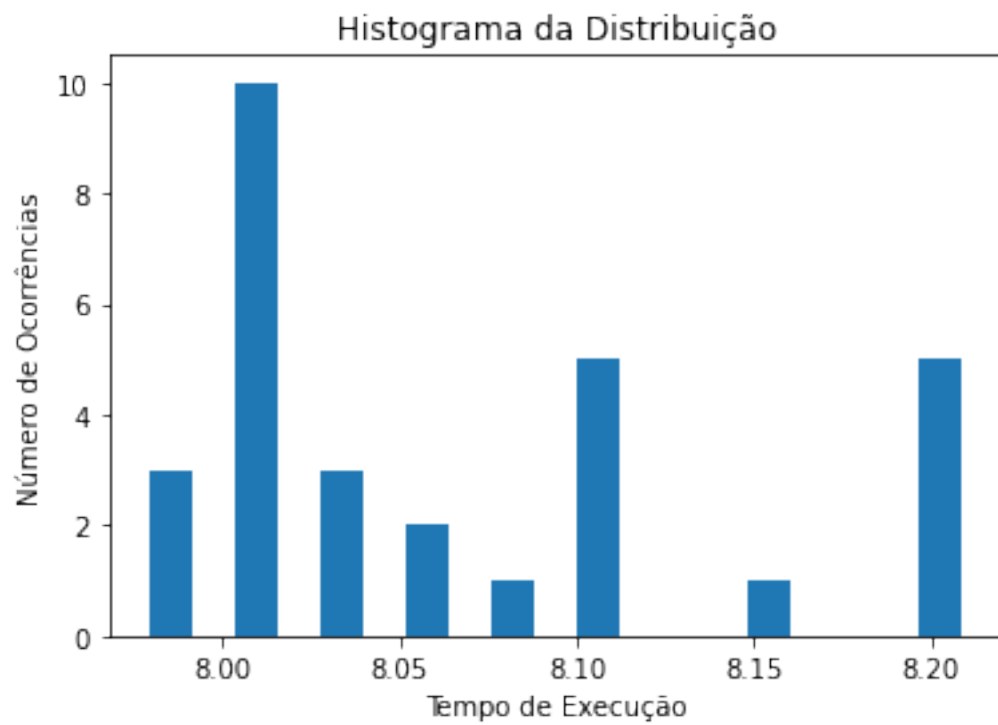


Statistics=0.27802, p=0.01529  
 Sample does not look Gaussian (reject H0)

### High Contention

```
[10]: ##bench_apply_ks_tests("C")
      #bench_apply_ks_tests("HiContention")
      bench_apply_ks_tests("High")
```

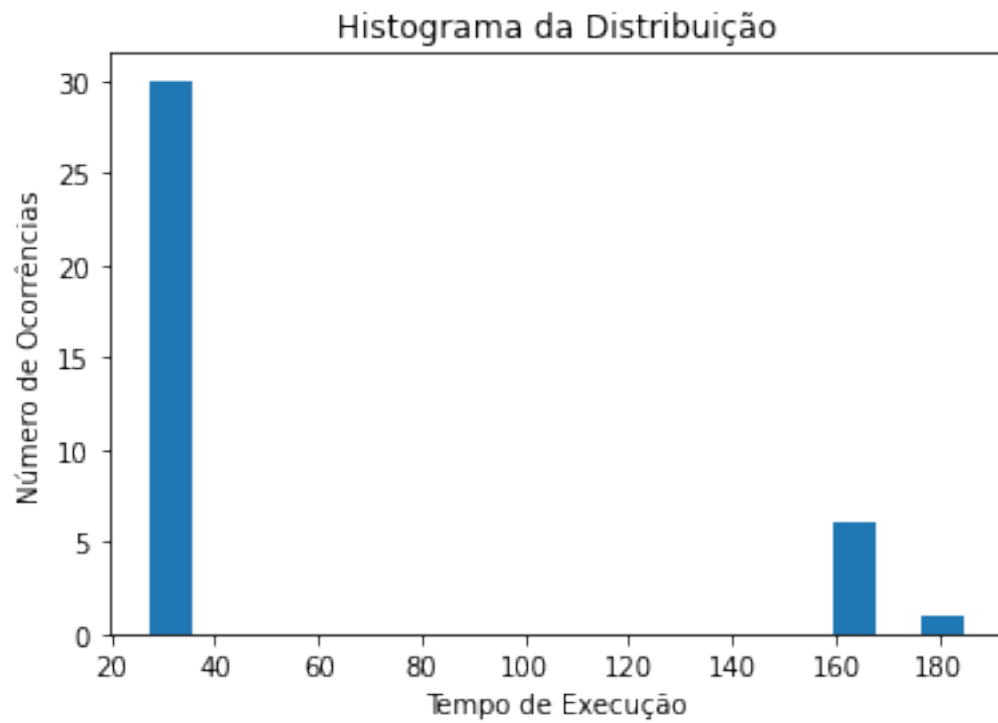
----- RTM-1 - High -----



Statistics=0.21769, p=0.09966  
Sample looks Gaussian (fail to reject H0)

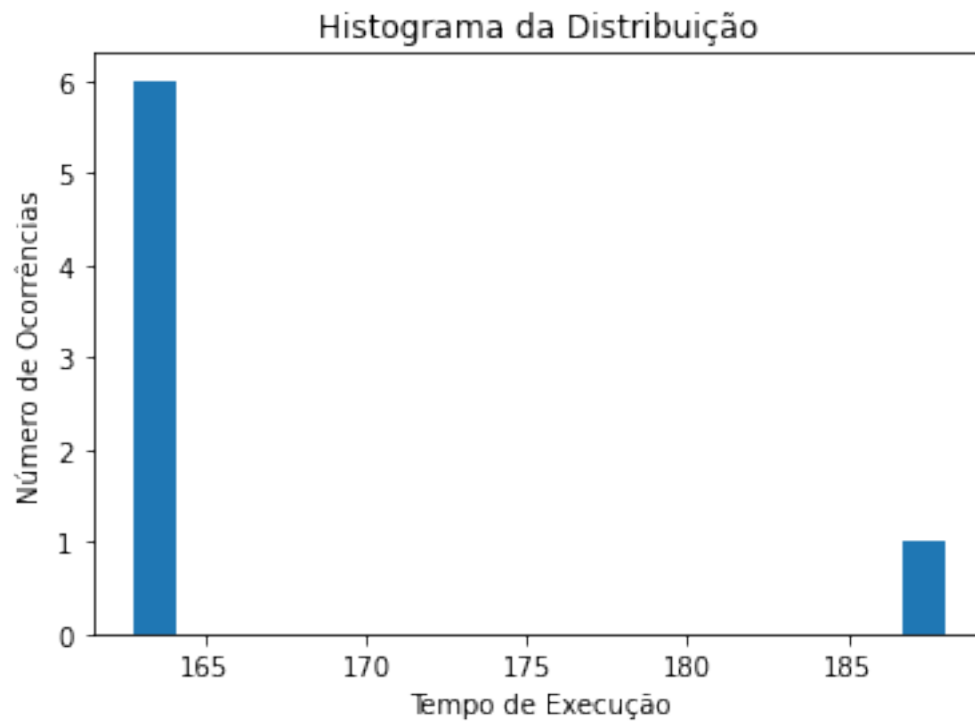
----- RTM-50 - High -----





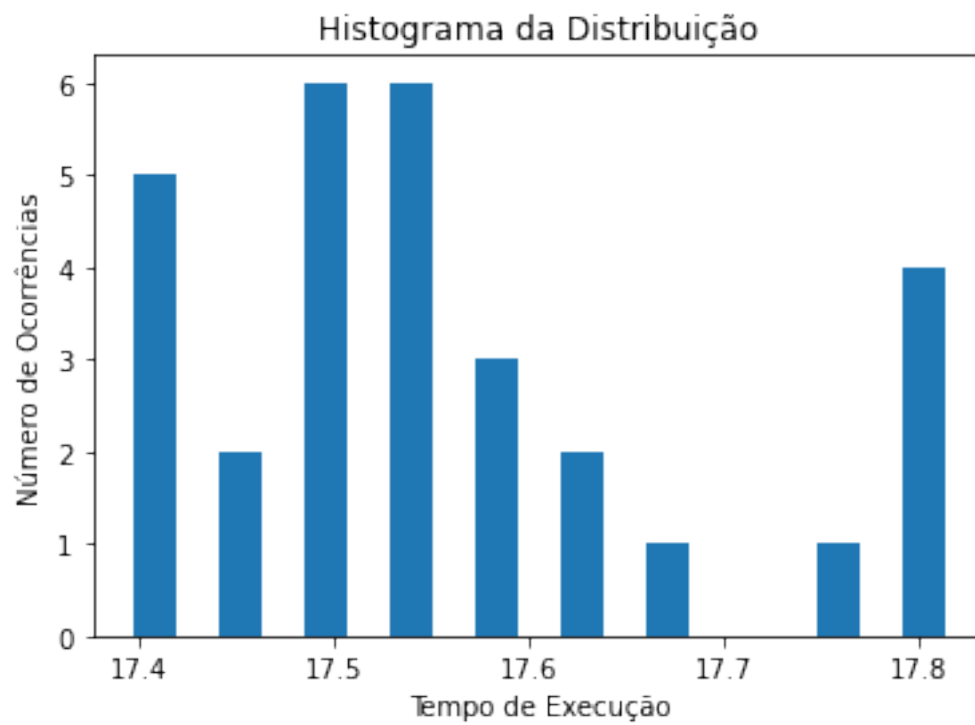
Statistics=0.48628, p=0.00000  
Sample does not look Gaussian (reject H0)

----- RTM-500 - High -----



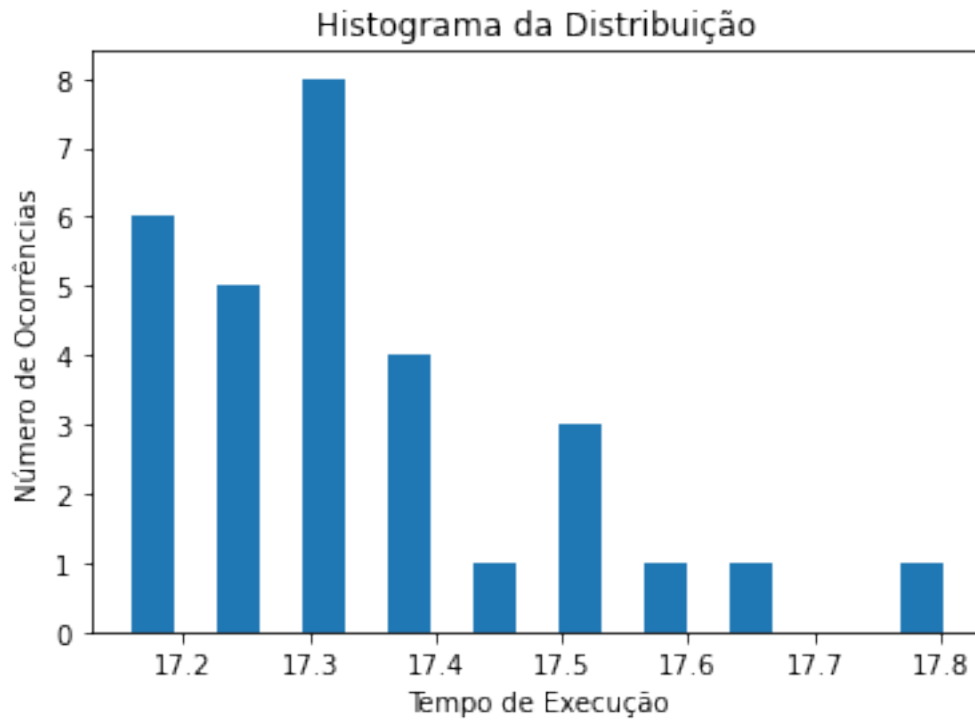
Statistics=0.47456, p=0.05733  
Sample looks Gaussian (fail to reject H0)

----- TinySTM - High -----



Statistics=0.19474, p=0.17978  
Sample looks Gaussian (fail to reject H0)

----- SwissTM - High -----



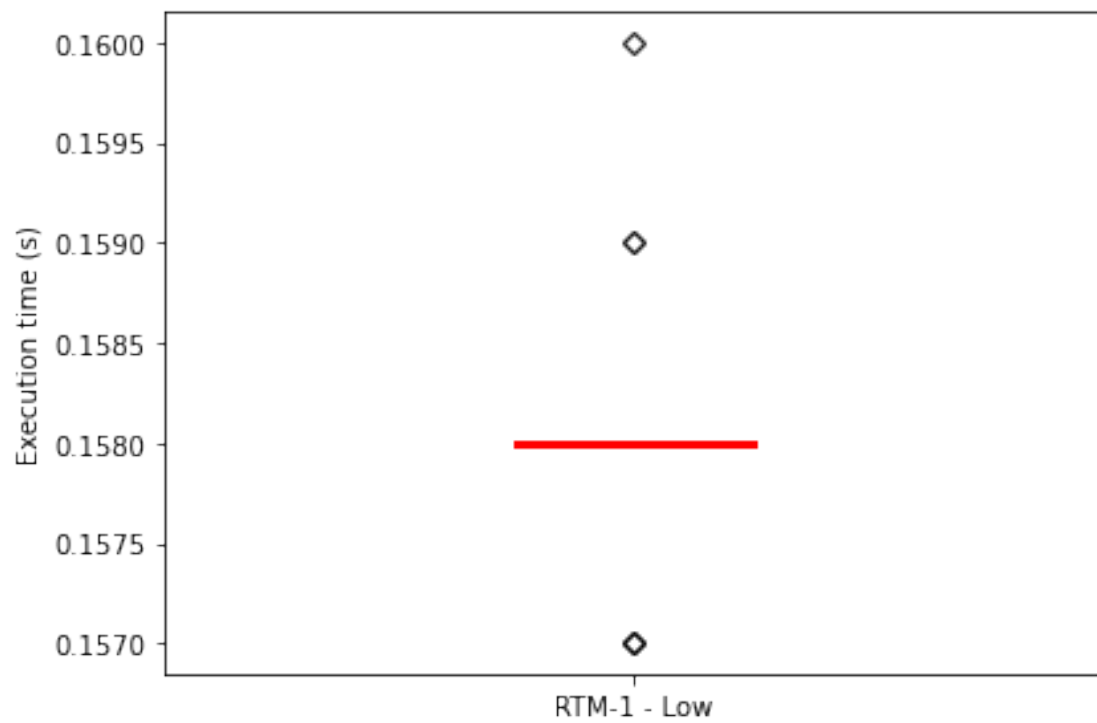
Statistics=0.14981, p=0.46644  
 Sample looks Gaussian (fail to reject H0)

### 1.2.3 Boxplots

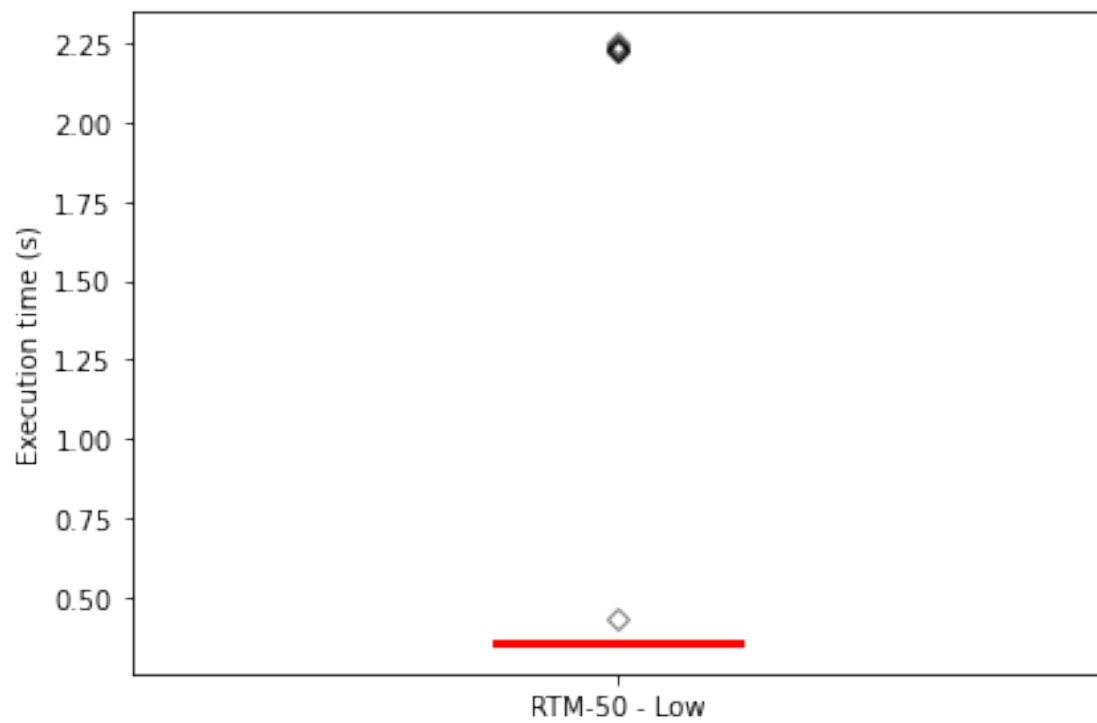
#### Low Contention

```
[11]: #bench_apply_boxplots("B")
      #bench_apply_boxplots("LoContention")
      bench_apply_boxplots("Low")
```

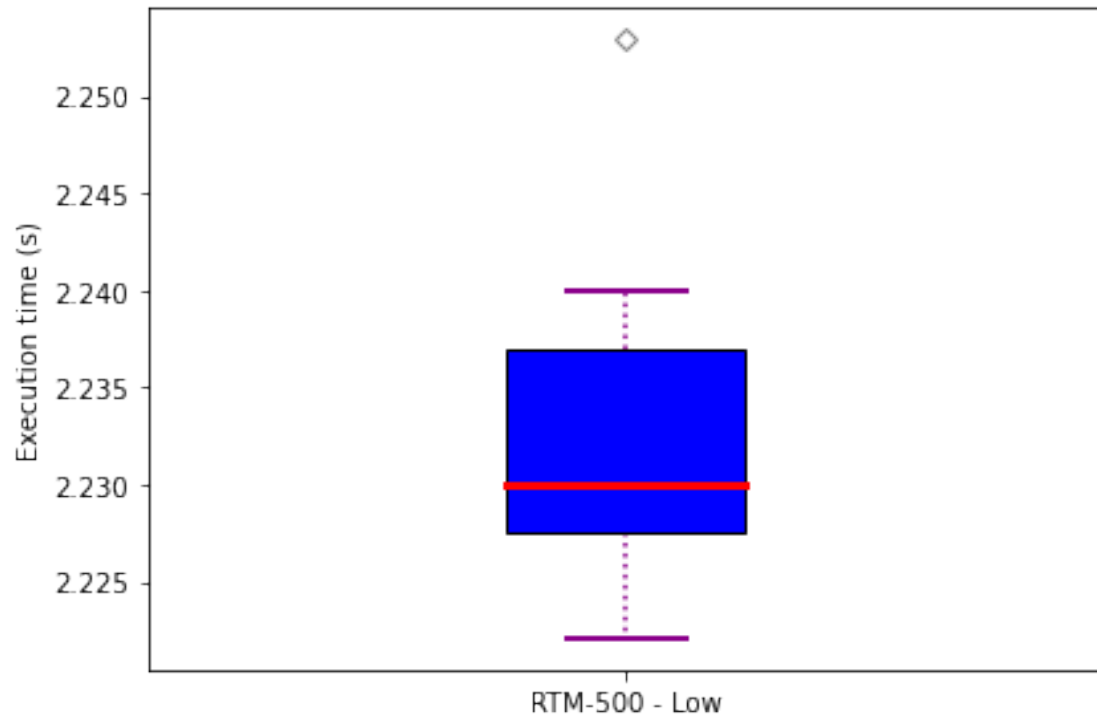
----- RTM-1 - Low -----



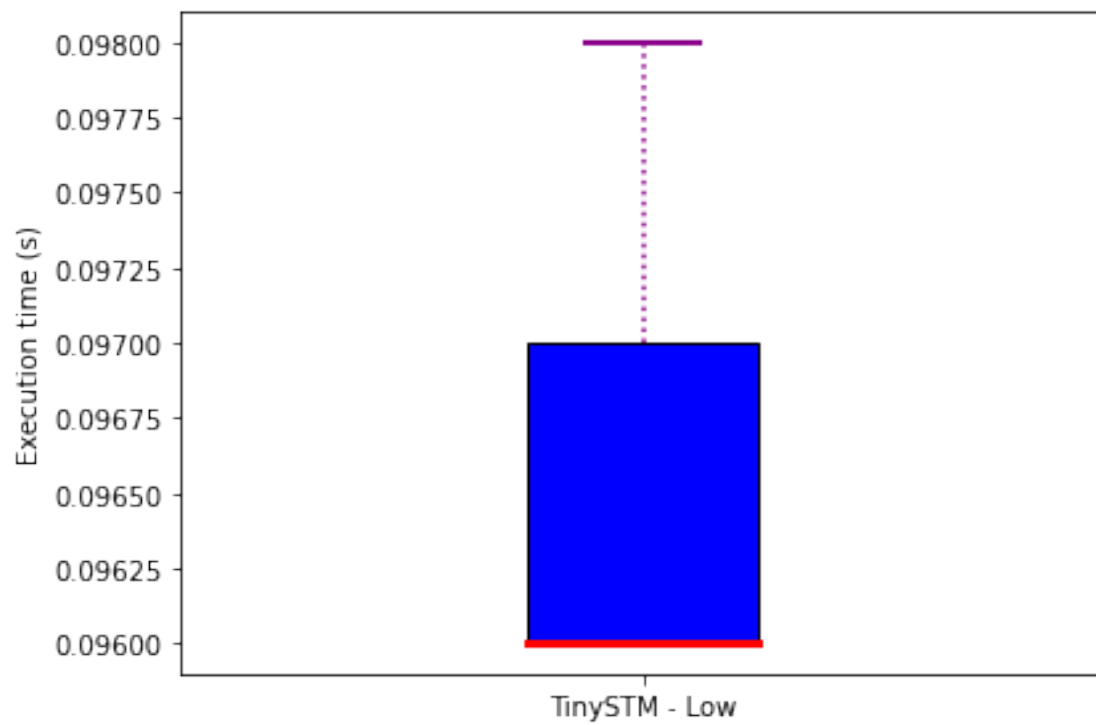
----- RTM-50 - Low -----



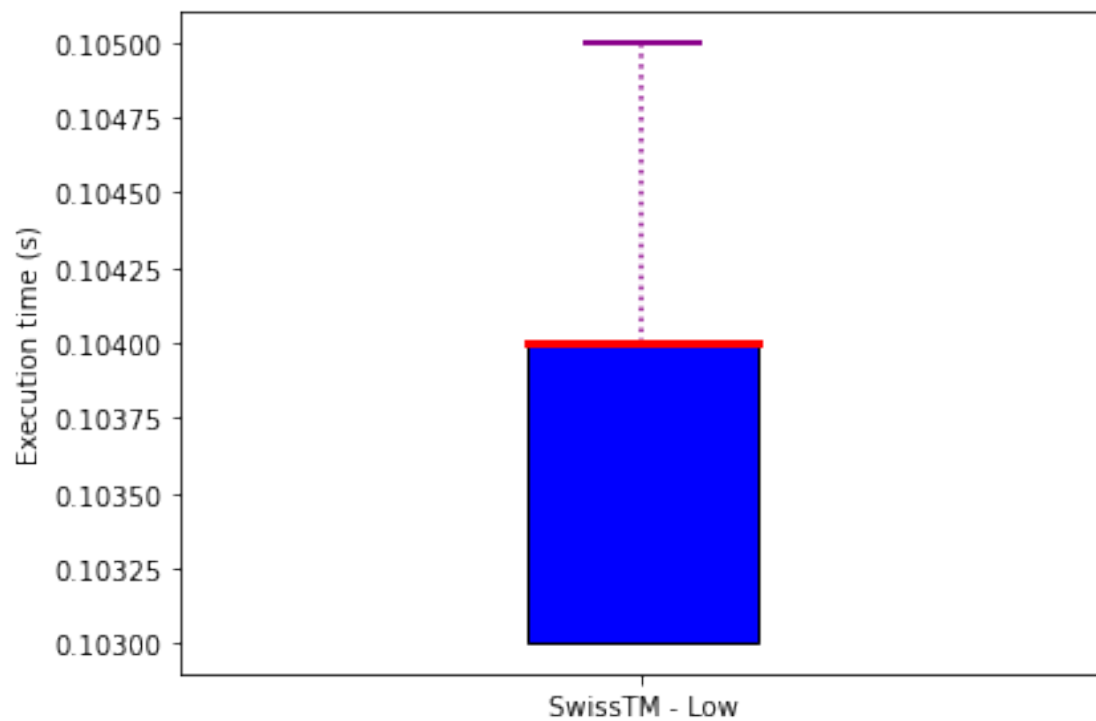
----- RTM-500 - Low -----



----- TinySTM - Low -----



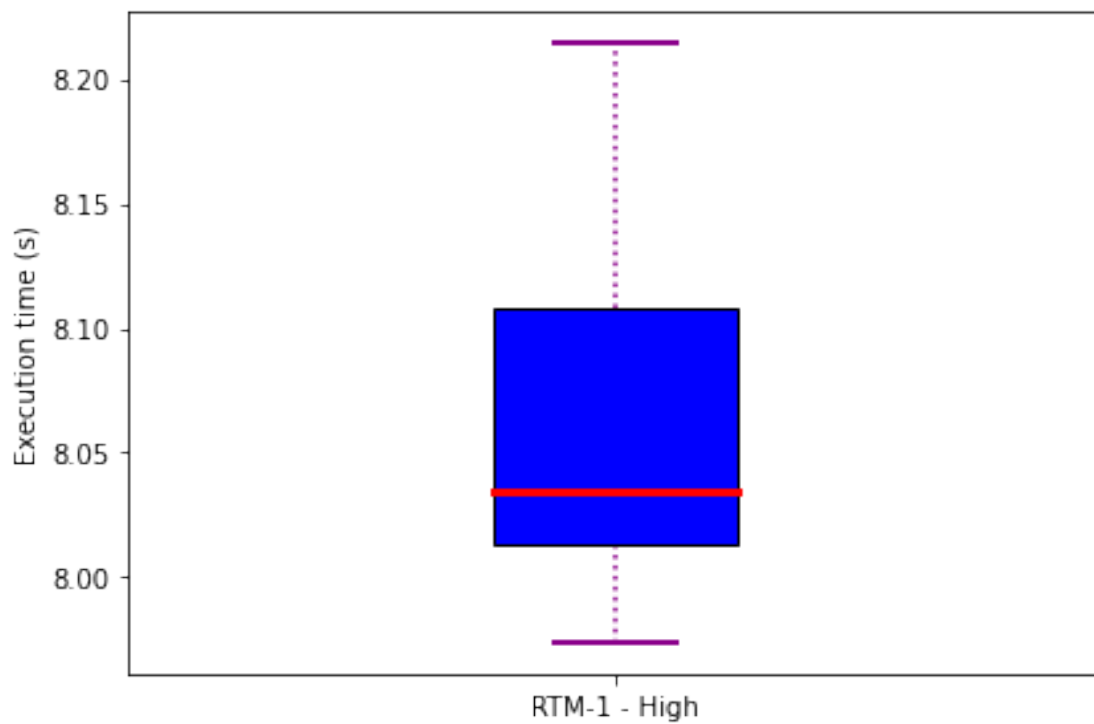
----- SwissTM - Low -----



## High Contention

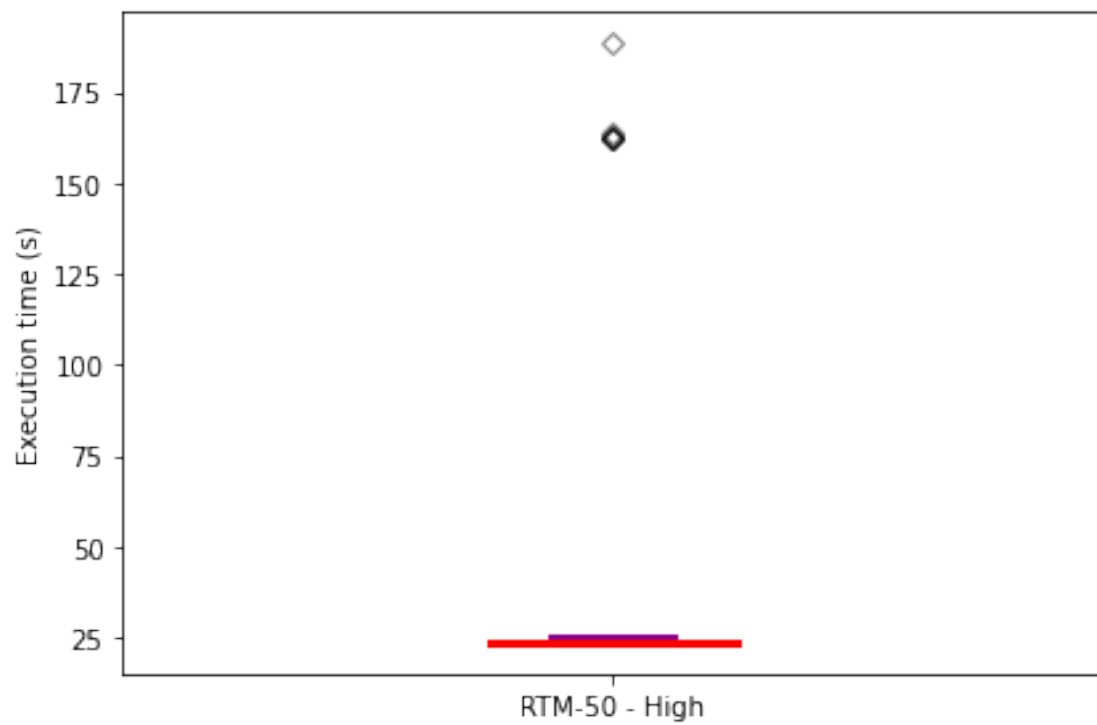
```
[12]: ##bench_apply_boxplots("C")  
      #bench_apply_boxplots("HiContention")  
      bench_apply_boxplots("High")
```

----- RTM-1 - High -----

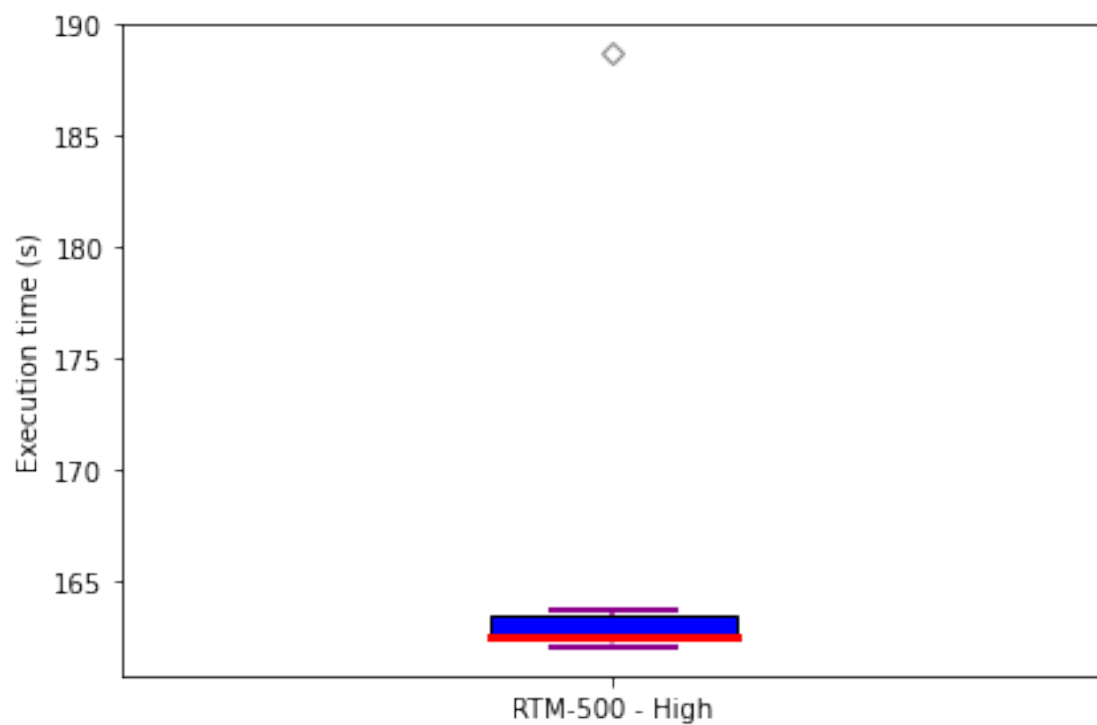


----- RTM-50 - High -----

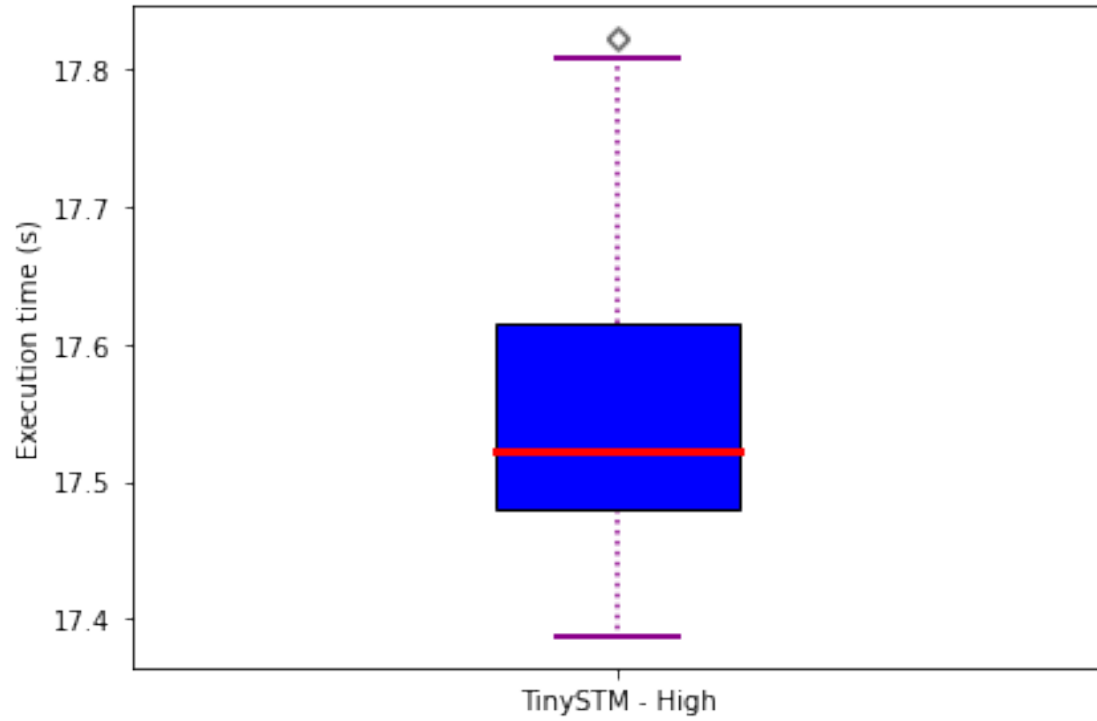




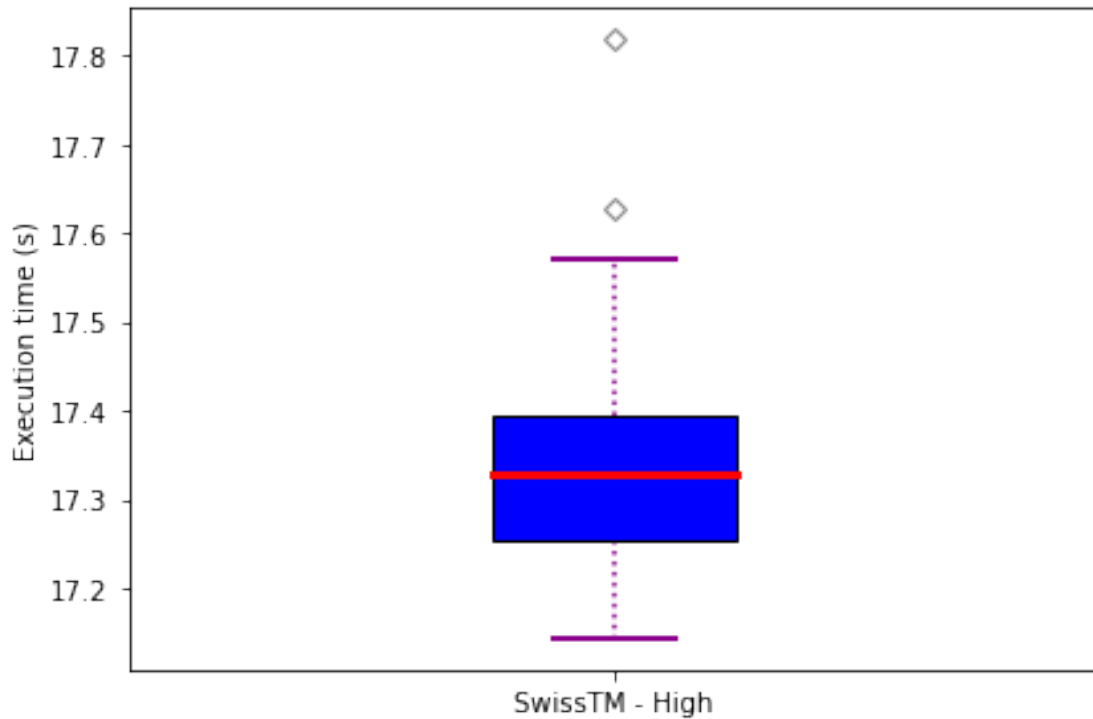
----- RTM-500 - High -----



----- TinySTM - High -----



----- SwissTM - High -----



## 1.2.4 T-Test and U-Test

### Low Contention

```
[13]: #bench_report_t_u_tests("B")
      #if("LoContention" in CLASSES):
      # bench_report_t_u_tests("LoContention")
      if("Low" in CLASSES):
          bench_report_t_u_tests("Low")
```

	(RTM-1[Low]) x (RTM-50[Low])
KS OK?	No
T-Test p	6.163134747051e-05
T-Test stat	-4.53492248
T-Test p<=0.05	Not normally distrib.
U-Test p	1.479276809093e-12
U-Test stat	0.00000000
U-Test p<=0.05	U-Test OK
	(RTM-1[Low]) x (RTM-500[Low])
KS OK?	No
T-Test p	2.724326014641e-15
T-Test stat	-531.32471927

T-Test $p \leq 0.05$	Not normally distrib.
U-Test p	1.723174877409e-05
U-Test stat	0.00000000
U-Test $p \leq 0.05$	U-Test OK
(RTM-1[Low]) x (TinySTM[Low])	
KS OK?	No
T-Test p	4.702264111288e-85
T-Test stat	328.81079534
T-Test $p \leq 0.05$	Not normally distrib.
U-Test p	6.737635900891e-12
U-Test stat	900.00000000
U-Test $p \leq 0.05$	U-Test OK
(RTM-1[Low]) x (SwissTM[Low])	
KS OK?	No
T-Test p	1.857006892332e-88
T-Test stat	268.46354627
T-Test $p \leq 0.05$	Not normally distrib.
U-Test p	1.001445308518e-11
U-Test stat	900.00000000
U-Test $p \leq 0.05$	U-Test OK
(RTM-50[Low]) x (RTM-500[Low])	
KS OK?	No
T-Test p	1.388779874047e-14
T-Test stat	-12.41272566
T-Test $p \leq 0.05$	Not normally distrib.
U-Test p	6.763024472988e-04
U-Test stat	24.50000000
U-Test $p \leq 0.05$	U-Test OK
(RTM-50[Low]) x (TinySTM[Low])	
KS OK?	No
T-Test p	1.332504047012e-05
T-Test stat	5.03924998
T-Test $p \leq 0.05$	Not normally distrib.
U-Test p	1.173965955031e-12
U-Test stat	1110.00000000
U-Test $p \leq 0.05$	U-Test OK
(RTM-50[Low]) x (SwissTM[Low])	
KS OK?	No
T-Test p	1.598941469713e-05
T-Test stat	4.97961226
T-Test $p \leq 0.05$	Not normally distrib.
U-Test p	1.580139554790e-12
U-Test stat	1110.00000000
U-Test $p \leq 0.05$	U-Test OK
(RTM-500[Low]) x (TinySTM[Low])	
KS OK?	No
T-Test p	2.407078519149e-15
T-Test stat	547.38291937

```

T-Test p<=0.05      Not normally distrib.
  U-Test p          9.482393082765e-06
  U-Test stat       210.00000000
U-Test p<=0.05      U-Test OK
                    (RTM-500[Low]) x (SwissTM[Low])
  KS OK?            No
  T-Test p          2.403934210780e-15
  T-Test stat       545.40820951
T-Test p<=0.05      Not normally distrib.
  U-Test p          2.022109778992e-05
  U-Test stat       210.00000000
U-Test p<=0.05      U-Test OK
                    (TinySTM[Low]) x (SwissTM[Low])
  KS OK?            No
  T-Test p          5.332981245073e-45
  T-Test stat       -44.41693179
T-Test p<=0.05      Not normally distrib.
  U-Test p          7.371481068518e-12
  U-Test stat       0.00000000
U-Test p<=0.05      U-Test OK

```

## High Contention

```

[14]: ##bench_report_t_u_tests("C")
      #if "HiContention" in CLASSES:
      #  bench_report_t_u_tests("HiContention")
      if "High" in CLASSES:
        bench_report_t_u_tests("High")

```

```

                    (RTM-1[High]) x (RTM-50[High])
  KS OK?            No
  T-Test p          5.535443884005e-05
  T-Test stat       -4.57058499
T-Test p<=0.05      Not normally distrib.
  U-Test p          2.598295687016e-12
  U-Test stat       0.00000000
U-Test p<=0.05      U-Test OK
                    (RTM-1[High]) x (RTM-500[High])
  KS OK?            Yes
  T-Test p          1.118142924568e-08
  T-Test stat       -42.60667500
T-Test p<=0.05      T-Test OK
  U-Test p          1.942601563095e-07
  U-Test stat       0.00000000
U-Test p<=0.05      U-Test OK
                    (RTM-1[High]) x (TinySTM[High])
  KS OK?            Yes
  T-Test p          1.291906743302e-80

```

T-Test stat	-340.88587149
T-Test p<=0.05	T-Test OK
U-Test p	2.871949066320e-11
U-Test stat	0.00000000
U-Test p<=0.05	U-Test OK
(RTM-1[High]) x (SwissTM[High])	
KS OK?	Yes
T-Test p	4.574344492313e-71
T-Test stat	-291.13558161
T-Test p<=0.05	T-Test OK
U-Test p	2.871949066320e-11
U-Test stat	0.00000000
U-Test p<=0.05	U-Test OK
(RTM-50[High]) x (RTM-500[High])	
KS OK?	No
T-Test p	1.433355153043e-14
T-Test stat	-11.51127476
T-Test p<=0.05	Not normally distrib.
U-Test p	7.516600648717e-04
U-Test stat	24.50000000
U-Test p<=0.05	U-Test OK
(RTM-50[High]) x (TinySTM[High])	
KS OK?	No
T-Test p	1.081496162054e-03
T-Test stat	3.55427743
T-Test p<=0.05	Not normally distrib.
U-Test p	2.598295687016e-12
U-Test stat	1110.00000000
U-Test p<=0.05	U-Test OK
(RTM-50[High]) x (SwissTM[High])	
KS OK?	No
T-Test p	1.013995278489e-03
T-Test stat	3.57720585
T-Test p<=0.05	Not normally distrib.
U-Test p	2.598295687016e-12
U-Test stat	1110.00000000
U-Test p<=0.05	U-Test OK
(RTM-500[High]) x (TinySTM[High])	
KS OK?	Yes
T-Test p	1.617020044421e-08
T-Test stat	40.05303263
T-Test p<=0.05	T-Test OK
U-Test p	1.942601563095e-07
U-Test stat	210.00000000
U-Test p<=0.05	U-Test OK
(RTM-500[High]) x (SwissTM[High])	
KS OK?	Yes
T-Test p	1.602467916511e-08

T-Test stat	40.11029512	
T-Test p<=0.05		T-Test OK
U-Test p	1.942601563095e-07	
U-Test stat	210.00000000	
U-Test p<=0.05		U-Test OK
(TinySTM[High]) x (SwissTM[High])		
KS OK?		Yes
T-Test p	4.233386391873e-07	
T-Test stat	5.72086270	
T-Test p<=0.05		T-Test OK
U-Test p	1.067005555706e-06	
U-Test stat	780.00000000	
U-Test p<=0.05		U-Test OK

### 1.2.5 Speedup charts

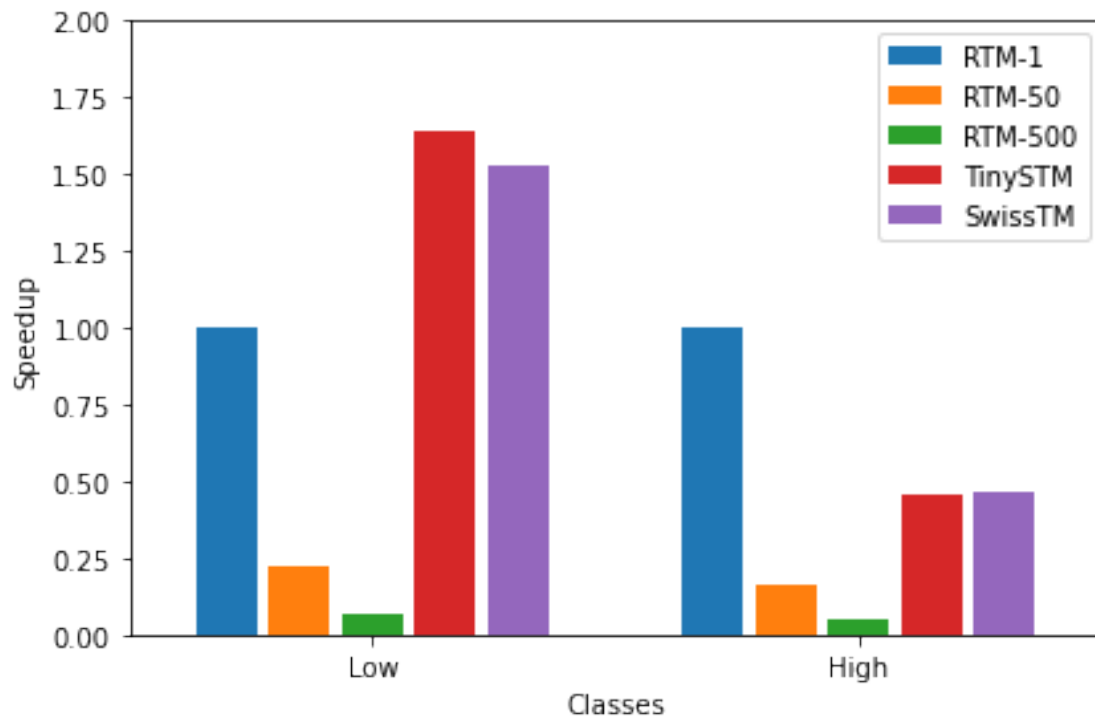
```
[15]: #0 speedup to comparando uma execução com ela mesma, isso preciso mudar

##Aqui provavelmente tenha que mudar
##Aqui usa as questões de versão e classe que não sei se traduzi corretamente.
    ↳pro meu caso
#print('-----', "Python", '-----')
#versions_gpu = [VER_PYTHON_CUDA]
#versions = [VER_RTM_INTEL_R1]
#versions2 = ["VER_RTM_INTEL_R1", "VER_STM_TINY", "VER_STM_SWISS"]

#bench_speedup_chart(VER_PYTHON_SERIAL, versions_gpu)
#bench_speedup_chart(VER_RTM_INTEL, versions)
#bench_speedup_chart(VER_RTM_INTEL_R1, versions)
#for v in VERSIONS:
v = VERSIONS[0]
bench_speedup_chart(v, VERSIONS)

#print("\n\n", '-----', "C++", '-----')
#if g_bench == "IS":
#    versions_gpu = [VER_CUDA]
#else:
#    versions_gpu = [VER_CUDA, VER_OPENACC]
#versions = [VER_SEQ]
#versions = [VER_STM_TINY]

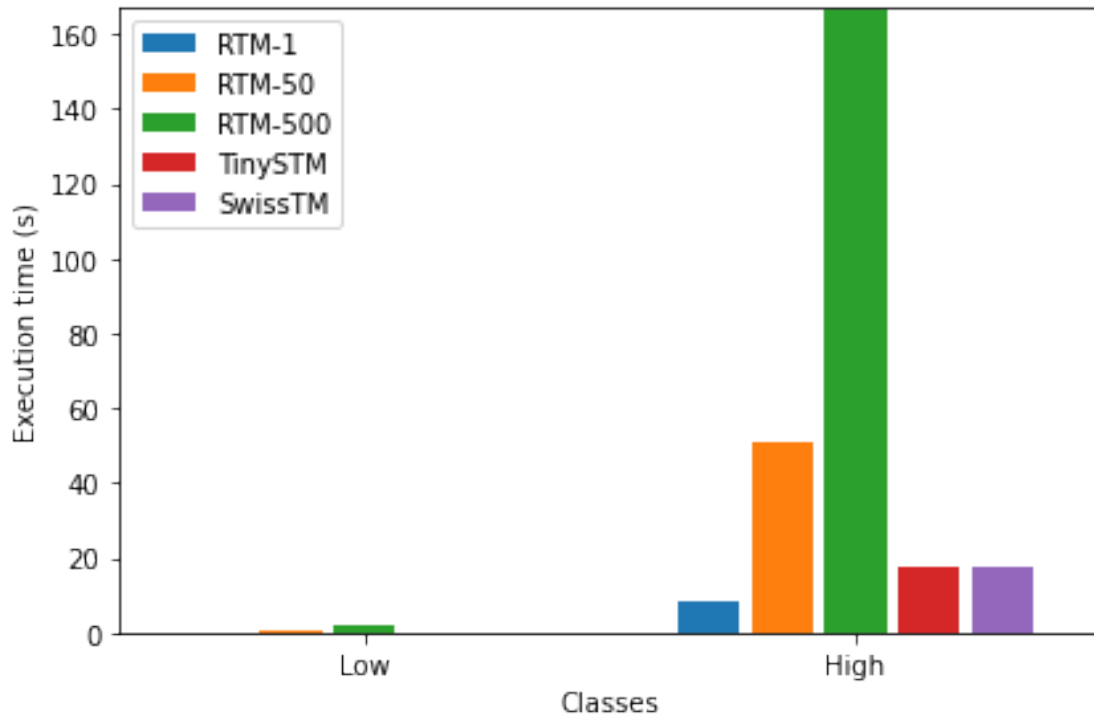
#bench_speedup_chart(VER_CPP_SERIAL, versions_gpu)
#bench_speedup_chart(VER_SEQ, versions)
#bench_speedup_chart(VER_STM_TINY, versions)
```



### 1.2.6 GPU comparison chart

```
[16]: bench_time_chart()
```





### 1.3 Main general view

#### 1.3.1 Utils

```
[17]: def load_npb_data_dictionary():
    global dic_dados_bench
    global dic_dados
    for b in BENCHS:
        dic_dados = {}
        load_data_dictionary(b)
        dic_dados_bench[b] = dict(dic_dados)

#END
```

```
[18]: ##Aqui também tive que mudar bastante coisa com classes e versões e não sei se tá correto
def npb_time_chart(classe):
    times = []
    bench_ids = range(1, len(BENCHS)*2+1, 2)

    #for v in VERSIONS_GPU:
    for v in VERSIONS:
        v_time = []
```

```

        for bench in BENCHS:
            dic_bench = dic_dados_bench[bench]
            if idx_dicionario(v, classe) in dic_bench.keys():
                time, a, b = _
            ↪ calc_stats(dic_bench[idx_dicionario(v, classe)]["times"])
            else:
                time = 0.0
                v_time.append(time)

        times.append(v_time)

#Chart
#desenha as barras no gráfico
fig, ax = plt.subplots()

bars = []
idx = -0.5
for t in times:
    bar = ax.bar(np.array(bench_ids)+idx, np.array(t), width=0.45)
    bars.append(bar)
    idx += 0.5

ax.set_xlabel('Benchmark')
ax.set_ylabel('Execution time (s)')
ax.set_xlim(0, 16)
ax.set_ylim(0.01, 60)

ax.set_title('Execution time')
ax.legend(tuple(map(name_versao, VERSIONS)))

ax.set_xticks(bench_ids)
ax.set_xticklabels(BENCHS)

#ax.set_yscale('log', base=2)
ax.set_yscale('log')

locs = [0.05, 0.1, 0.5, 1, 5, 10, 20, 40, 60]
ax.yaxis.set_minor_locator(ticker.FixedLocator(locs))
ax.yaxis.set_major_locator(ticker.NullLocator())

ax.yaxis.set_minor_formatter(ticker.ScalarFormatter())

#for b in bars:
#         ax.bar_label(b, padding=3, fmt='%4.2f')

fig.tight_layout()

```

```

plt.show() #mostra o gráfico
#END

def npb_speedup_chart(classe):
    speedups = []
    bench_ids = range(1, len(BENCHS)*2+1, 2)

    #for v in VERSIONS_GPU:
    for v in VERSIONS:
        v_speedup = []

        for bench in BENCHS:
            dic_bench = dic_dados_bench[bench]

            if idx_dicionario(v, classe) in dic_bench.keys():
                time_serial = 1.0
                #if "PYTHON" in v:
                #         time_serial, a, b =
→ calc_stats(dic_bench[idx_dicionario(VER_PYTHON_SERIAL, classe)]["times"])
                #time_serial, a, b =
→ calc_stats(dic_bench[idx_dicionario(VER_RTM_INTEL, classe)]["times"])
                time_serial, a, b =
→ calc_stats(dic_bench[idx_dicionario(VER_RTM_INTEL_R1, classe)]["times"])
                #else:
                #         time_serial, a, b =
→ calc_stats(dic_bench[idx_dicionario(VER_CPP_SERIAL, classe)]["times"])
                #
                #if idx_dicionario(v, classe) in dic_bench.
→ keys():
                time, a, b =
→ calc_stats(dic_bench[idx_dicionario(v, classe)]["times"])
                v_speedup.append(time_serial/time)
            else:
                v_speedup.append(-100.0)

        speedups.append(v_speedup)

    #Chart
    #desenha as barras no gráfico
    fig, ax = plt.subplots()

    bars = []
    idx = -0.5
    for s in speedups:
        bar = ax.bar(np.array(bench_ids)+idx, np.array(s), width=0.45)

```

```

        bars.append(bar)
        idx += 0.5

    ax.set_xlabel('Benchmark')
    ax.set_ylabel('Speedup')
    ax.set_xlim(0, 16)
    ax.set_ylim(1, 2000)

    ax.set_title('Speedup')
    ax.legend(tuple(map(name_versao, VERSIONS)))

    ax.set_xticks(bench_ids)
    ax.set_xticklabels(BENCHS)

    ax.set_yscale('log')

    locs = [1, 5, 10, 50, 100, 500, 1000, 1500, 2000]
    ax.yaxis.set_minor_locator(ticker.FixedLocator(locs))
    ax.yaxis.set_major_locator(ticker.NullLocator())

    ax.yaxis.set_minor_formatter(ticker.ScalarFormatter())

    #for b in bars:
    #    ax.bar_label(b, padding=3, fmt='%4.1f')

    fig.tight_layout()

    plt.show() #mostra o gráfico
#END

```

### 1.3.2 Charts

```

[19]: load_npb_data_dictionary()

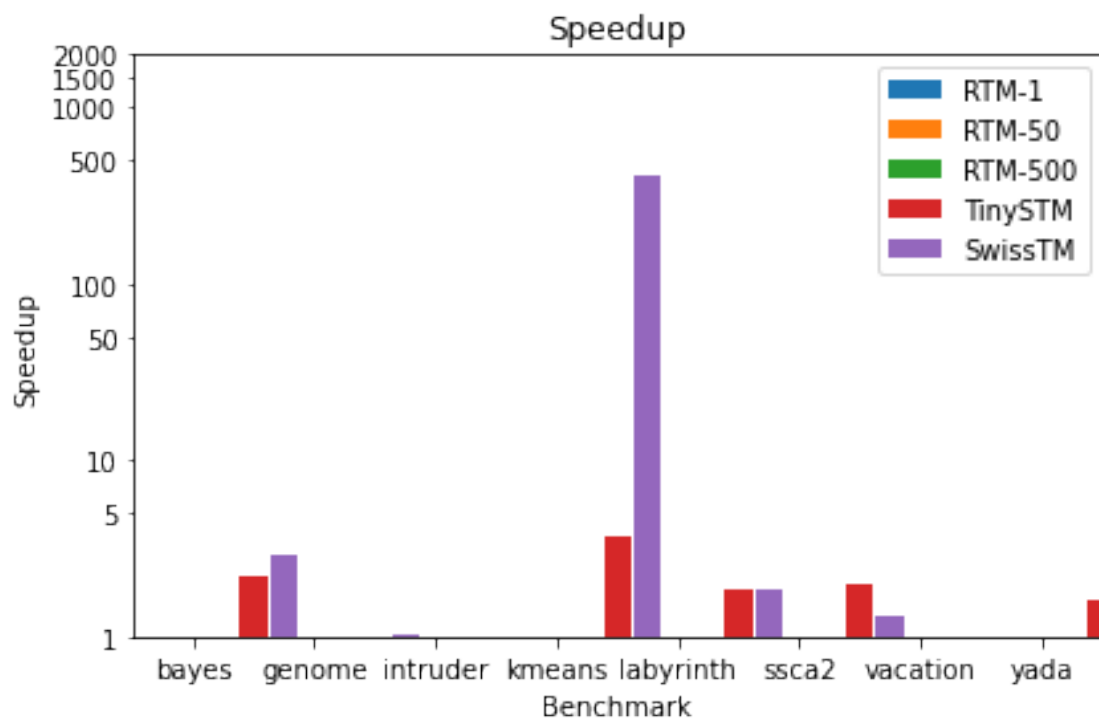
#print('\n', '-----', "Class B", '-----')
#npb_speedup_chart("B")
#npb_speedup_chart("LoContention")
npb_speedup_chart("Low")

#npb_time_chart("B")
#npb_time_chart("LoContention")
npb_time_chart("Low")

```

Gerando bayes ...  
 bayes OK  
 Gerando genome ...

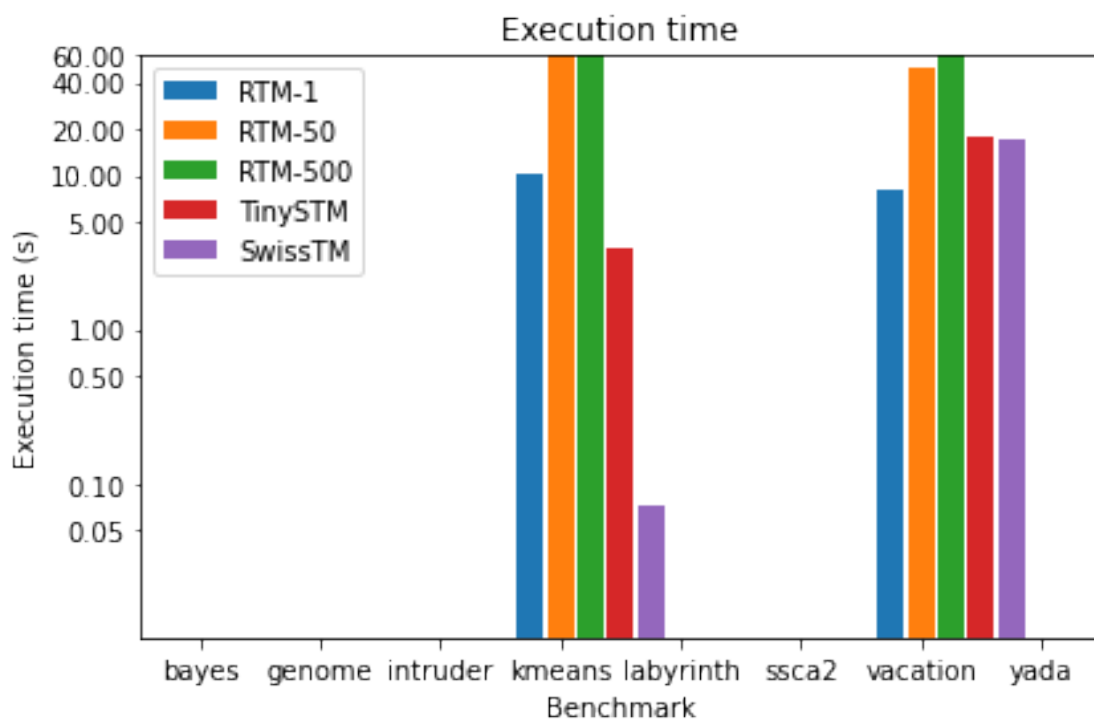
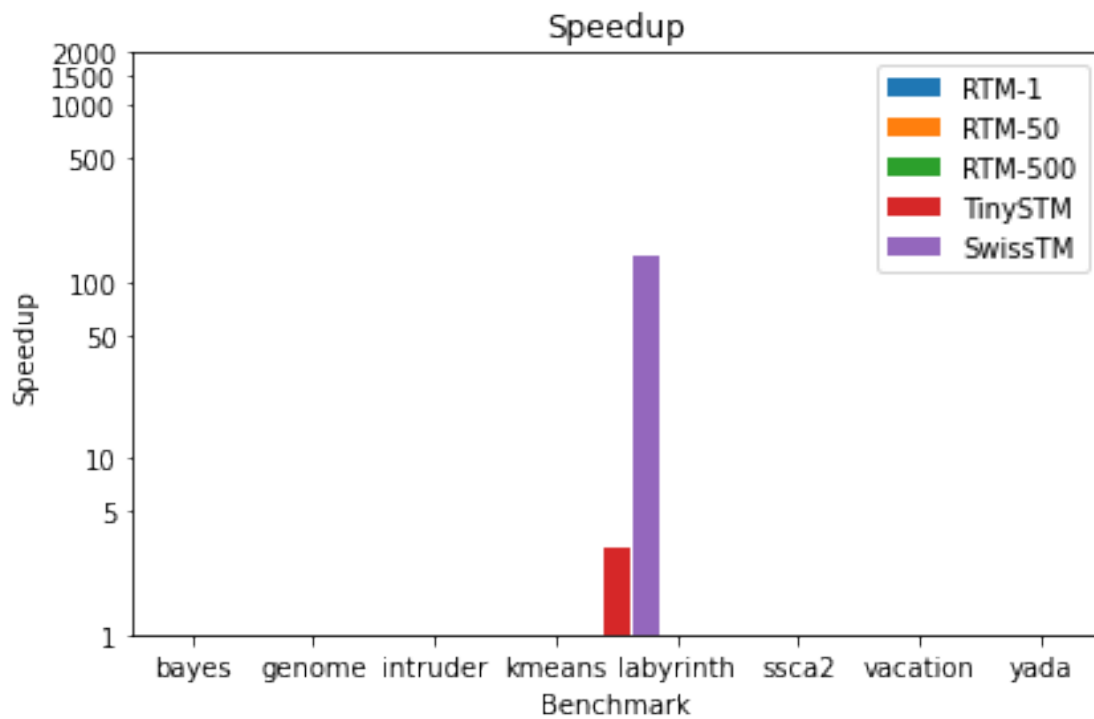
genome OK  
 Gerando intruder ...  
 intruder OK  
 Gerando kmeans ...  
 kmeans OK  
 Gerando labyrinth ...  
 labyrinth OK  
 Gerando ssca2 ...  
 ssca2 OK  
 Gerando vacation ...  
 vacation OK  
 Gerando yada ...  
 yada OK





```
[20]: ##print('\n', '-----', "Class C", '-----')
      ##npb_speedup_chart("C")
      #if "HiContention" in CLASSES:
      # npb_speedup_chart("HiContention")
      if "High" in CLASSES:
          npb_speedup_chart("High")

      ##npb_time_chart("C")
      # npb_time_chart("HiContention")
      npb_time_chart("High")
```



```

[21]: import os
get_ipython().system(
    "apt update >> /dev/null && apt install texlive-xetex
    ↪texlive-fonts-recommended texlive-generic-recommended >> /dev/null"
)

notebookpath="/content/drive/MyDrive/Colab Notebooks/"
file_name = "NPB_statistics - Frederico.ipynb"
drive_mount_point = "/content/drive/"
gdrive_home = os.path.join(drive_mount_point, "My Drive/Colab Notebooks/
    ↪Arquivos")

if not os.path.isfile(os.path.join(notebookpath, file_name)):
    raise ValueError(f"file '{file_name}' not found in path '{notebookpath}'.")

pdfNum = 0
while os.path.isfile(os.path.join(gdrive_home, file_name.split(".")[0] +
    ↪str(pdfNum) + ".pdf")):
    pdfNum = pdfNum + 1
filename = file_name.split(".")[0] + str(pdfNum) + ".pdf"

try:
    get_ipython().system(
        "jupyter nbconvert --output-dir=\""+gdrive_home+"\"
    ↪\""+notebookpath+file_name+"\" --to pdf --output=\""+filename+"\"
    )
except:
    print("nbconvert error")

try:
    from google.colab import files

    file_name = file_name.split(".")[0] + ".pdf"
    files.download(gdrive_home + file_name)
except:
    print("File Download Unsuccessful. Saved in Google Drive")

print("File ready to be Downloaded and Saved to Drive")

```

WARNING: apt does not have a stable CLI interface. Use with caution in scripts.

WARNING: apt does not have a stable CLI interface. Use with caution in scripts.

[NbConvertApp] Converting notebook /content/drive/MyDrive/Colab  
Notebooks/NPB\_statistics - Frederico.ipynb to pdf



```

[NbConvertApp] Support files will be in NPB_statistics - Frederico17_files/
[NbConvertApp] Making directory ./NPB_statistics - Frederico17_files
[NbConvertApp] Making directory ./NPB_statistics - Frederico17_files
[NbConvertApp] Making directory ./NPB_statistics - Frederico17_files
[NbConvertApp] Making directory ./NPB_statistics - Frederico17_files
[NbConvertApp] Making directory ./NPB_statistics - Frederico17_files
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[NbConvertApp] Making directory ./NPB_statistics - Frederico17_files
[NbConvertApp] Making directory ./NPB_statistics - Frederico17_files
[NbConvertApp] Writing 132539 bytes to ./notebook.tex
[NbConvertApp] Building PDF
[NbConvertApp] Running xelatex 3 times: ['xelatex', './notebook.tex', '-quiet']
[NbConvertApp] Running bibtex 1 time: ['bibtex', './notebook']
[NbConvertApp] WARNING | bibtex had problems, most likely because there were no
citations
[NbConvertApp] PDF successfully created
[NbConvertApp] Writing 242425 bytes to /content/drive/My Drive/Colab
Notebooks/Arquivos/NPB_statistics - Frederico17.pdf
File Download Unsuccessful. Saved in Google Drive
File ready to be Downloaded and Saved to Drive

```