Taichi - 12.06.2024

Auteurs

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Description

Taichi est un langage de programmation intégré à python qui permet d'écrire du code hautement performant en utilisant le parrallélisme et la vectorisation. Il est principalement utilisé pour la simulation physique, la rendu d'image et l'apprentissage profond. Taichi est conçu pour être facile à utiliser et à apprendre, il est également très flexible et extensible. Il est open source et est disponible sur github.

Taichi fait du code parallele automatique, ce qui veut dire que le developpeur n'a pas besoin de spécifier quoi que ce soit, juste ajouter l'annotation @ti.kernel à la fonction qu'il veut paralléliser.

Installation

Pour installer taichi, il suffit d'exécuter la commande suivante:

```
$ pip install taichi -U
```

In [ ]:
```
%pip install taichi
```

```
Requirement already satisfied: taichi in c:\users\humai\appdata\local\packages\py
thonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python
311\site-packages (1.7.1)
Requirement already satisfied: numpy in c:\users\humai\appdata\local\packages\pyt
honsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python3
11\site-packages (from taichi) (1.26.4)
Requirement already satisfied: colorama in c:\users\humai\appdata\local\packages
\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\pyt
hon311\site-packages (from taichi) (0.4.6)
Requirement already satisfied: dill in c:\users\humai\appdata\local\packages\pyth
onsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python31
1\site-packages (from taichi) (0.3.8)
Requirement already satisfied: rich in c:\users\humai\appdata\local\packages\pyth
onsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python31
1\site-packages (from taichi) (13.7.1)
Requirement already satisfied: markdown-it-py>=2.2.0 in c:\users\humai\appdata\lo
cal\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-
packages\python311\site-packages (from rich->taichi) (3.0.0)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in c:\users\humai\appdata
\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\loc
al-packages\python311\site-packages (from rich->taichi) (2.17.2)
Requirement already satisfied: mdurl~=0.1 in c:\users\humai\appdata\local\package
s\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\py
thon311\site-packages (from markdown-it-py>=2.2.0->rich->taichi) (0.1.2)
Note: you may need to restart the kernel to use updated packages.
```

Exemples

Les librairies ci-dessous sont nécéssaire pour les exemples qui suivent, ces librairies ne sont pas nécéssaire au bon fonctionnement de Taichi

In [ ]:
```
%pip install requests pillow matplotlib numpy
```

```
Requirement already satisfied: requests in c:\users\humai\appdata\local\packages
\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\pyt
hon311\site-packages (2.31.0)
Requirement already satisfied: pillow in c:\users\humai\appdata\local\packages\py
thonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python
311\site-packages (10.3.0)
Requirement already satisfied: matplotlib in c:\users\humai\appdata\local\package
s\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\py
thon311\site-packages (3.9.0)
Requirement already satisfied: numpy in c:\users\humai\appdata\local\packages\pyt
honsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python3
11\site-packages (1.26.4)
Requirement already satisfied: charset-normalizer<4,>=2 in c:\users\humai\appdata
\local\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\loc
al-packages\python311\site-packages (from requests) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in c:\users\humai\appdata\local\packa
ges\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages
\python311\site-packages (from requests) (3.7)
Requirement already satisfied: urllib3<3,>=1.21.1 in c:\users\humai\appdata\local
\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-pac
kages\python311\site-packages (from requests) (2.2.1)
Requirement already satisfied: certifi>=2017.4.17 in c:\users\humai\appdata\local
\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-pac
kages\python311\site-packages (from requests) (2024.2.2)
Requirement already satisfied: contourpy>=1.0.1 in c:\users\humai\appdata\local\p
ackages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packa
ges\python311\site-packages (from matplotlib) (1.2.1)
Requirement already satisfied: cycler>=0.10 in c:\users\humai\appdata\local\packa
ges\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages
\python311\site-packages (from matplotlib) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in c:\users\humai\appdata\local
\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-pac
kages\python311\site-packages (from matplotlib) (4.53.0)
Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\humai\appdata\local
\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-pac
kages\python311\site-packages (from matplotlib) (1.4.5)
Requirement already satisfied: packaging>=20.0 in c:\users\humai\appdata\local\pa
ckages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packag
es\python311\site-packages (from matplotlib) (23.2)
Requirement already satisfied: pyparsing>=2.3.1 in c:\users\humai\appdata\local\p
ackages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packa
ges\python311\site-packages (from matplotlib) (3.1.2)
Requirement already satisfied: python-dateutil>=2.7 in c:\users\humai\appdata\loc
al\packages\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-p
ackages\python311\site-packages (from matplotlib) (2.8.2)
Requirement already satisfied: six>=1.5 in c:\users\humai\appdata\local\packages
\pythonsoftwarefoundation.python.3.11_qbz5n2kfra8p0\localcache\local-packages\pyt
hon311\site-packages (from python-dateutil>=2.7->matplotlib) (1.16.0)
Note: you may need to restart the kernel to use updated packages.
```

Compteur de nombre premier (exemple de Taichi)

Exemple fourni par Taichi pour illustrer comment Taichi peut améliorer la performance d'un code Python. Cet exemple compte le nombre de nombre premier inférieur à N

Python

In [ ]:
```
import time

N = 1000000

def is_prime(n: int):
    result = True
    for k in range(2, int(n**0.5) + 1):
        if n % k == 0:
            result = False
            break
    return result

def count_primes(n: int) -> int:
    count = 0
    for k in range(2, n):
        if is_prime(k):
            count += 1

    return count

start = time.perf_counter()
print(f"Number of primes: {count_primes(N)}")
time_python = time.perf_counter() - start;
print(f"time elapsed: {time_python}/s")
```

```
Number of primes: 78498
time elapsed: 4.08143199999904/s
```

Taichi : CPU

In [ ]:
```
import taichi as ti
ti.init(arch=ti.cpu)

@ti.func
def is_prime(n: int):
    result = True
    for k in range(2, int(n**0.5) + 1):
        if n % k == 0:
            result = False
            break
    return result

@ti.kernel
def count_primes(n: int) -> int:
    count = 0
    for k in range(2, n):
        if is_prime(k):
            count += 1

    return count

start = time.perf_counter()
print(f"Number of primes: {count_primes(N)}")
time_cpu = time.perf_counter() - start
print(f"time elapsed: {time_cpu}/s")
```

```
[Taichi] Starting on arch=x64
Number of primes: 78498
time elapsed: 0.08143159999963245/s
```

Taichi : GPU

In [ ]:
```
import taichi as ti
ti.init(arch=ti.gpu)

@ti.func
def is_prime(n: int):
    result = True
    for k in range(2, int(n**0.5) + 1):
        if n % k == 0:
            result = False
            break
    return result

@ti.kernel
def count_primes(n: int) -> int:
    count = 0
    for k in range(2, n):
        if is_prime(k):
            count += 1

    return count

start = time.perf_counter()
print(f"Number of primes: {count_primes(N)}")
time_gpu = time.perf_counter() - start
print(f"time elapsed: {time_gpu}/s")
```

```
[Taichi] Starting on arch=cuda
Number of primes: 78498
time elapsed: 0.10463290000006964/s
```

Taichi : Cuda

In [ ]:
```
import taichi as ti
ti.init(arch=ti.cuda)

@ti.func
def is_prime(n: int):
    result = True
    for k in range(2, int(n**0.5) + 1):
        if n % k == 0:
            result = False
            break
    return result

@ti.kernel
def count_primes(n: int) -> int:
    count = 0
    for k in range(2, n):
        if is_prime(k):
            count += 1

    return count

start = time.perf_counter()
print(f"Number of primes: {count_primes(N)}")
```

```
time_cuda = time.perf_counter() - start
print(f"time elapsed: {time_cuda}/s")
```

```
[Taichi] Starting on arch=cuda
Number of primes: 78498
time elapsed: 0.09687579999990703/s
```

Taichi : Vulkan

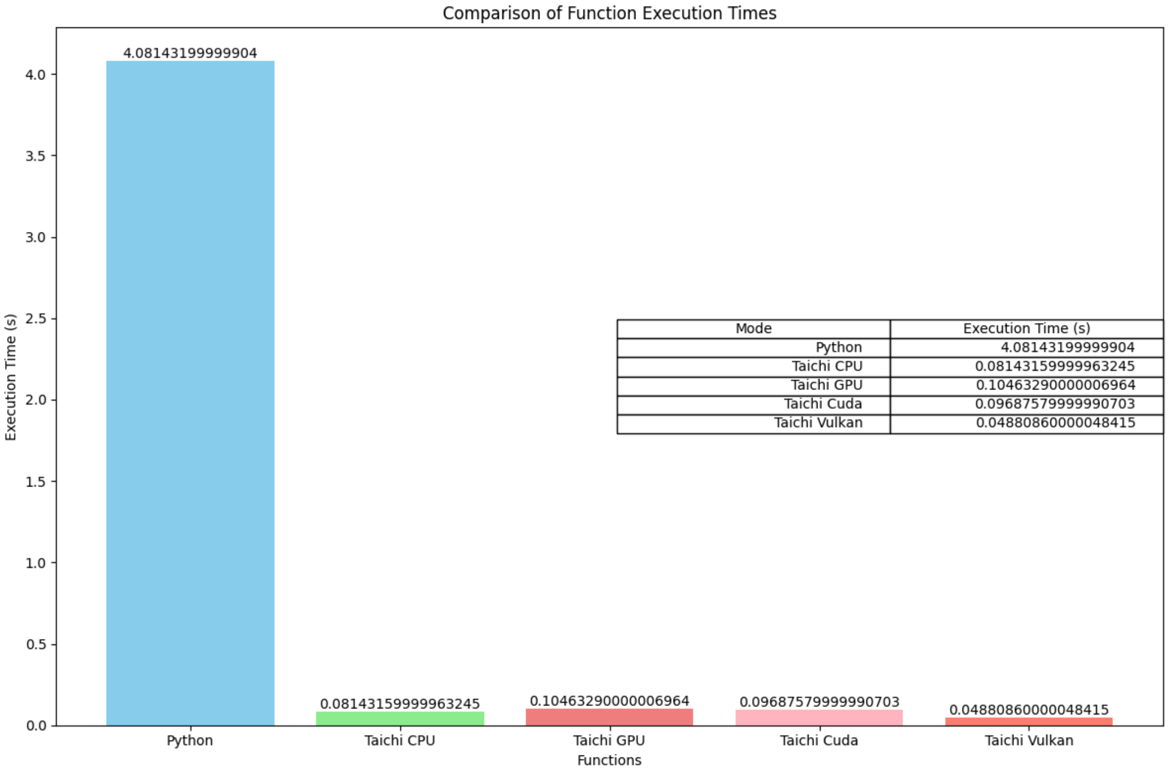
In [ ]:
```
import taichi as ti
ti.init(arch=ti.vulkan)

@ti.func
def is_prime(n: int):
    result = True
    for k in range(2, int(n**0.5) + 1):
        if n % k == 0:
            result = False
            break
    return result

@ti.kernel
def count_primes(n: int) -> int:
    count = 0
    for k in range(2, n):
        if is_prime(k):
            count += 1

    return count

start = time.perf_counter()
print(f"Number of primes: {count_primes(N)}")
time_vulkan = time.perf_counter() - start
print(f"time elapsed: {time_vulkan}/s")
```

```
[Taichi] Starting on arch=vulkan
Number of primes: 78498
time elapsed: 0.04880860000048415/s
```

Comparaison

In [ ]:
```
import matplotlib.pyplot as plt

# Execution times
execution_times = [time_python, time_cpu, time_gpu, time_cuda, time_vulkan]

function_names = ['Python', 'Taichi CPU', 'Taichi GPU', 'Taichi Cuda', 'Taichi V
colors = ['skyblue', 'lightgreen', 'lightcoral', 'lightpink', 'salmon']

# bar chart
# bar chart
fig, ax = plt.subplots(figsize=(12, 8))
bars = ax.bar(function_names, execution_times, color=colors)
ax.set_xlabel('Functions')
ax.set_ylabel('Execution Time (s)')
ax.set_title('Comparison of Function Execution Times')

for bar, time in zip(bars, execution_times):
    height = bar.get_height()
    ax.text(bar.get_x() + bar.get_width() / 2, height, f'{time}', ha='center', v
```

```
plt.subplot(1, 2, 2)
plt.axis('off')  # Hide axes
table_data = list(zip(function_names, execution_times))
plt.table(cellText=table_data, colLabels=['Mode', 'Execution Time (s)'], loc='ce
plt.tight_layout()

plt.show()
```

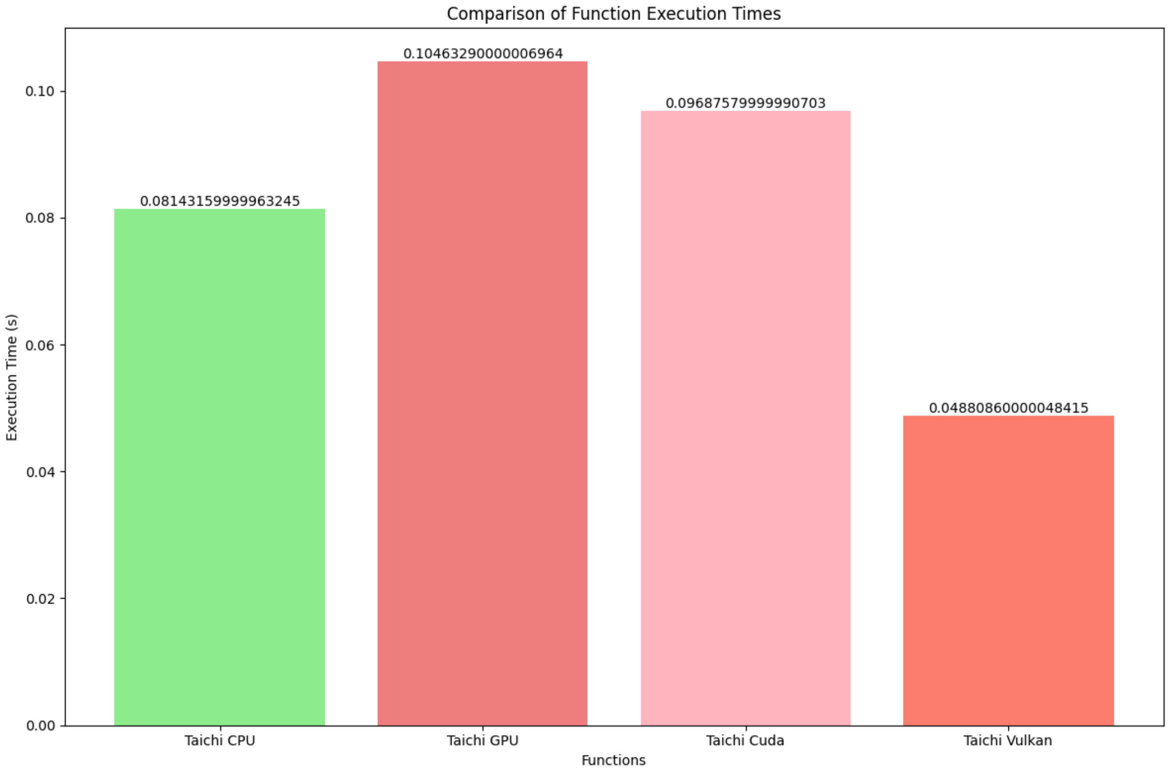


On peut observer que le temps d'exécution est significativement réduit avec Taichi

Même observation mais en ne gardant que les backends Taichi

In [ ]:
```
import matplotlib.pyplot as plt

# Execution times
execution_times = [time_cpu, time_gpu, time_cuda, time_vulkan]

function_names = ['Taichi CPU', 'Taichi GPU', 'Taichi Cuda', 'Taichi Vulkan']
colors = ['lightgreen', 'lightcoral', 'lightpink', 'salmon']


# bar chart
fig, ax = plt.subplots(figsize=(12, 8))
bars = ax.bar(function_names, execution_times, color=colors)
ax.set_xlabel('Functions')
ax.set_ylabel('Execution Time (s)')
ax.set_title('Comparison of Function Execution Times')

for bar, time in zip(bars, execution_times):
    height = bar.get_height()
    ax.text(bar.get_x() + bar.get_width() / 2, height, f'{time}', ha='center', v

plt.tight_layout()
```

```
plt.show()
```



Pour ce cas applicatif, le backend Vulkan est plus performant. Les backends GPU et Cuda utilise la même architecture

Calculs de matrices

Python

In [ ]:

```
import random
import time


def matrix_multiplication():
    for i in range(N):
        for j in range(N):
            temp = 0.0
            for k in range(N):
                temp += A[i][k] * B[k][j]
            result[i][j] = temp


# Définir la taille des matrices
N = 500

# Générer des matrices aléatoires
A = [[random.random() for _ in range(N)] for _ in range(N)]
B = [[random.random() for _ in range(N)] for _ in range(N)]
result = [[0 for _ in range(N)] for _ in range(N)]

# Effectuer la multiplication des matrices
start = time.perf_counter()
matrix_multiplication()
```

```
time_python2 = time.perf_counter() - start

# for row in result[:5]:
#     print(row[:5])

print(f"time elapsed: {time_python2}/s")
```

```
time elapsed: 14.123857399999906/s
```

Taichi : GPU

In [ ]:
```
import taichi as ti
import time

ti.init(arch=ti.gpu)

@ti.kernel
def matrix_multiplication():
    for i in range(N):
        for j in range(N):
            temp = 0.0
            for k in range(N):
                temp += A[i, k] * B[k, j]
            result[i, j] = temp


# Définir la taille des matrices
N = 500

# Définir les matrices en tant que champs Taichi
A = ti.field(ti.f32, shape=(N, N))
B = ti.field(ti.f32, shape=(N, N))
result = ti.field(ti.f32, shape=(N, N))

# Remplir les matrices avec des valeurs aléatoires
A.from_numpy(np.random.rand(N, N).astype(np.float32))
B.from_numpy(np.random.rand(N, N).astype(np.float32))

# Effectuer la multiplication des matrices avec Taichi
start = time.perf_counter()
matrix_multiplication()
time_taichi = time.perf_counter() - start

# print(result.to_numpy())

print(f"time elapsed: {time_taichi}/s")
```

```
[Taichi] Starting on arch=cuda
time elapsed: 0.07734379999965313/s
```

Python + Numpy

In [ ]:
```
import numpy as np
import time

N = 500

# Définir deux matrices de taille plus importante
A = np.random.rand(N, N)
B = np.random.rand(N, N)
```

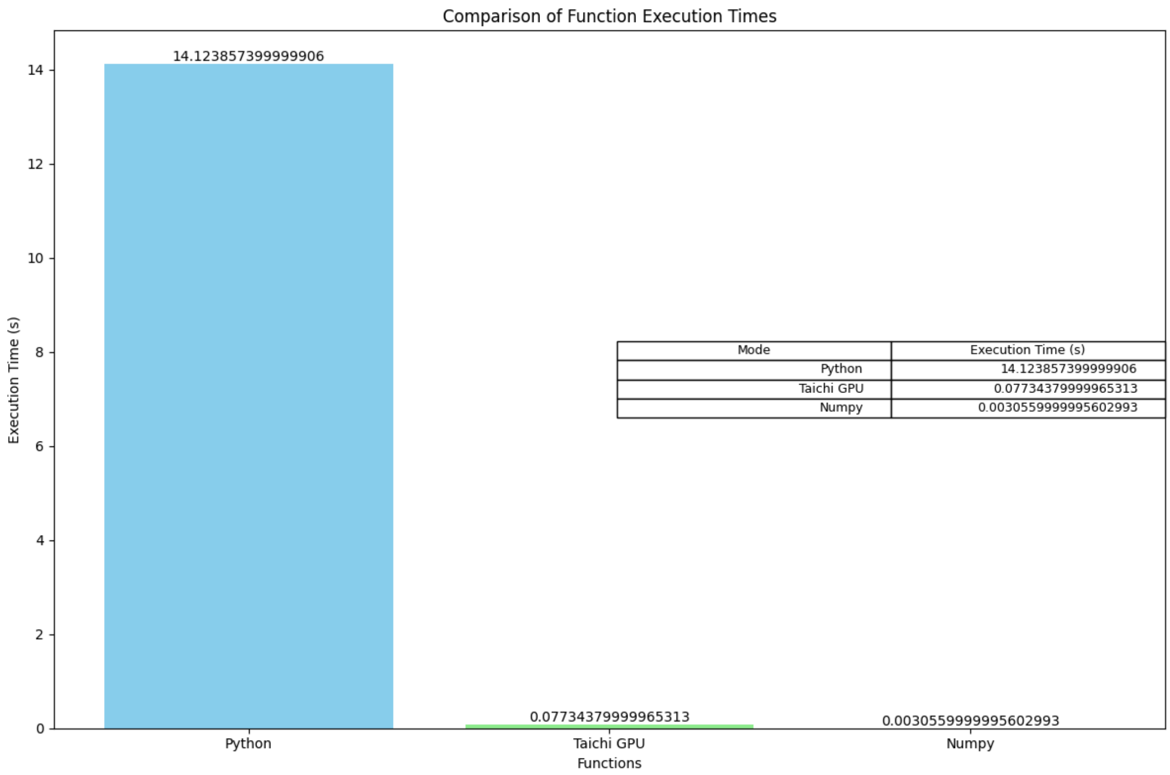
```
print(A)

# Multiplication de matrices avec NumPy
start = time.perf_counter()
result = np.dot(A, B)
time_numpy = time.perf_counter() - start

# print(result)

print(f"time elapsed: {time_numpy}/s")
```

```
[[0.9524906  0.24293516 0.97852597 ... 0.09861398 0.35515075 0.99541294]
 [0.6830298  0.63281913 0.0118799  ... 0.17070792 0.48118077 0.80409534]
 [0.85134215 0.70469624 0.1059937  ... 0.81064557 0.25958534 0.35278382]
 ...
 [0.64857507 0.80519082 0.83477724 ... 0.54586227 0.54951771 0.60987288]
 [0.24436528 0.47141184 0.5056125  ... 0.35094093 0.95560906 0.8831467 ]
 [0.120994   0.41617938 0.03950257 ... 0.86336342 0.53029776 0.86404379]]
time elapsed: 0.0030559999995602993/s
```

Comparaison

In [ ]:

```
import matplotlib.pyplot as plt

# Execution times
execution_times = [time_python2, time_taichi, time_numpy]

function_names = ['Python', 'Taichi GPU', 'Numpy']
colors = ['skyblue', 'lightgreen', 'lightcoral']

# bar chart
# bar chart
fig, ax = plt.subplots(figsize=(12, 8))
bars = ax.bar(function_names, execution_times, color=colors)
ax.set_xlabel('Functions')
ax.set_ylabel('Execution Time (s)')
ax.set_title('Comparison of Function Execution Times')

for bar, time in zip(bars, execution_times):
    height = bar.get_height()
    ax.text(bar.get_x() + bar.get_width() / 2, height, f'{time}', ha='center', v

plt.subplot(1, 2, 2)
plt.axis('off')  # Hide axes
table_data = list(zip(function_names, execution_times))
plt.table(cellText=table_data, colLabels=['Mode', 'Execution Time (s)'], loc='ce
plt.tight_layout()

plt.show()
```



Traitement d'image

Comparaison entre les performances de taichi et python sur un traitement d'images en appliquant un filtre de convolution sur une image.

In [ ]:

```
import time
import numpy as np
import requests
from PIL import Image
import matplotlib.pyplot as plt
from io import BytesIO

# variables globales

# l'imge est en 4k
url = "https://images7.alphacoders.com/127/1272410.jpg"

def load_image_from_url(url):
    response = requests.get(url)
    img = Image.open(BytesIO(response.content))
    return img

# afficher une image depuis le repertoire local courant
def display_image_from_local(filename):
    img = Image.open(filename)
    # sans les axes
    plt.axis('off')
    plt.imshow(np.array(img), cmap='gray')
    plt.show()

# enregistrer l'image
def save_image(image, filename):
    image.save(filename)
```

```python
# Charger l'image
image = load_image_from_url(url)

# Sauvegarder l'image
save_image(image, "../images/image.jpg")

display_image_from_local("../images/image.jpg")
```

Python grayscale

In [ ]:
```python
def to_greyscale(image):
    # Convertir l'image en tableau numpy
    img_array = np.array(image)

    # Vérifier si l'image a une couche alpha (RGBA) et l'enlever si c'est le cas
    if img_array.shape[2] == 4:
        img_array = img_array[:, :, :3]

    # Utiliser la formule de luminance pour convertir en niveaux de gris
    greyscale_array = 0.299 * img_array[:, :, 0] + 0.587 * img_array[:, :, 1] +

    # Convertir le tableau numpy en image PIL
    greyscale_image = Image.fromarray(greyscale_array.astype('uint8'))

    return greyscale_image

# Convertir en niveaux de gris manuellement
start_time = time.time()
greyscale_image = to_greyscale(image)
time_gray_python = time.time() - start_time

save_image(greyscale_image, "../images/vanila_greyscale.jpg")

display_image_from_local("../images/vanila_greyscale.jpg")

# Temps de conversion
print(f"Temps de conversion: {time_gray_python:.6f}s")
```

```
Temps de conversion: 0.288999s
```

Taichi grayscale

In [ ]:
```
# init taichi
import taichi as ti

ti.init(arch=ti.gpu)

def to_greyscale_ti(image):
    # Convertir l'image en tableau numpy
    img_array = np.array(image)

    # Vérifier si l'image a une couche alpha (RGBA) et l'enlever si c'est le cas
    if img_array.shape[2] == 4:
        img_array = img_array[:, :, :3]

    # Dimensions de l'image
    h, w, c = img_array.shape

    # Définir les champs Taichi pour l'image couleur et l'image en niveaux de gr
    color_image = ti.Vector.field(3, dtype=ti.u8, shape=(h, w))
    greyscale_image = ti.field(dtype=ti.u8, shape=(h, w))

    # Copier les données de l'image couleur dans le champ Taichi
    color_image.from_numpy(img_array)

    # Kernel Taichi pour convertir l'image en niveaux de gris
    @ti.kernel
    def to_greyscale():
        for i, j in ti.ndrange(h, w):
            r = color_image[i, j][0]
            g = color_image[i, j][1]
            b = color_image[i, j][2]
            grey = ti.u8(0.299 * r + 0.587 * g + 0.114 * b)
            greyscale_image[i, j] = grey

    # Exécuter le kernel
    to_greyscale()

    # Convertir le champ Taichi en tableau numpy
    greyscale_array = greyscale_image.to_numpy()
```

```
    # Convertir le tableau numpy en image PIL
    greyscale_image_pil = Image.fromarray(greyscale_array)

    return greyscale_image_pil

# Convertir en niveaux de gris manuellement
start_time = time.time()
greyscale_image_ti = to_greyscale_ti(image)
time_gray_taichi = time.time() - start_time

# enregistrer l'image
save_image(greyscale_image_ti, "../images/taichi_greyscale.jpg")

display_image_from_local("../images/taichi_greyscale.jpg")

# Temps de conversion
print(f"Temps de conversion: {time_gray_taichi:.6f}s")
```

```
[Taichi] Starting on arch=cuda
```

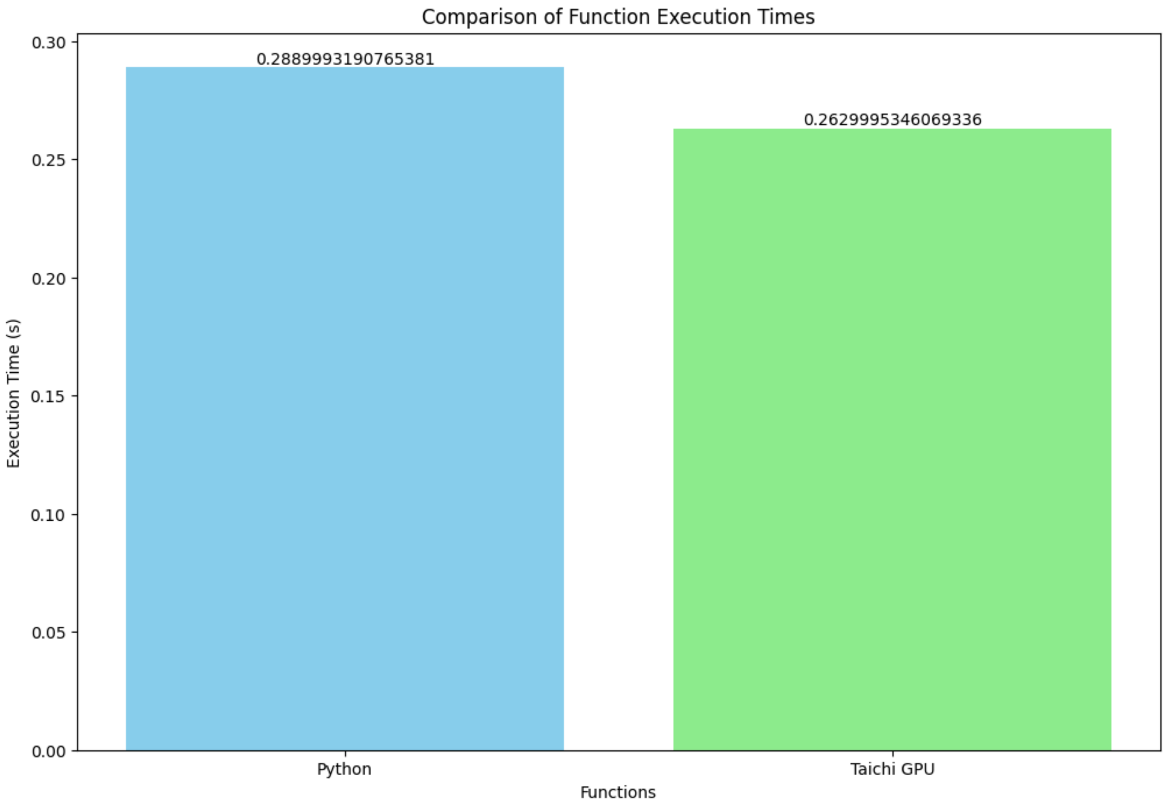
```
Temps de conversion: 0.263000s
```

Comparaison

In [ ]:

```
import matplotlib.pyplot as plt

# Execution times
execution_times = [time_gray_python, time_gray_taichi]

function_names = ['Python', 'Taichi GPU']
colors = ['skyblue', 'lightgreen']

# bar chart
# bar chart
fig, ax = plt.subplots(figsize=(12, 8))
bars = ax.bar(function_names, execution_times, color=colors)
ax.set_xlabel('Functions')
ax.set_ylabel('Execution Time (s)')
ax.set_title('Comparison of Function Execution Times')

for bar, time in zip(bars, execution_times):
    height = bar.get_height()
```

```
    ax.text(bar.get_x() + bar.get_width() / 2, height, f'{time}', ha='center', v

plt.show()
```



Performance équivalente entre python et taichi

Conclusion

Selon le type d'application et le type de calcul il est possible de grandement améliorer les performances grace à Taichi. Numpy étant basé sur des bibliothèques optimisées en C et Fortran, ce qui lui permet de bénéficier pleinement de la vectorisation, se montre plus performant que Taichi dans certains cas comme des calculs sur des tableaux.

Contrairement a ce qui est mis en avant, Taichi n'est pas si simple a prendre en main. Nous avons passé beaucoup de temps à essayer de convertir des codes pythons pour Taichi sans forcément finir par y arriver.

Taichi semble être un outil très puissant pour le calcul parallèle et la vectorisation, mais il semble avoir des problèmes avec les types de données et les calculs itératifs. Il est donc difficile de comparer les gains de performances avec python de base. L'utilisation de Taichi est plus adaptée à du traitement graphique ou calcul vectoriel.