

A6

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#implementation 1

```
import numpy as np

np.random.seed(1234)

MC_N = 10**3

x = np.random.uniform(0,1,MC_N)*2-1
y = np.random.uniform(0,1,MC_N)*2-1

t = np.sqrt(x**2+y**2)

pi_hat = 4*sum(t<=1)/MC_N
print(pi_hat)
```

3.06

#implementation 2

```
import numpy as np

np.random.seed(1234)
MC_N = 10**3
count = 0

for MC_i in range(MC_N):
    x_i = np.random.uniform(0, 1) * 2 - 1
    y_i = np.random.uniform(0, 1) * 2 - 1
    t_i = np.sqrt(x_i**2+y_i**2)

    if t_i <=1:
        count = count+1

pi_hat = 4*count/MC_N
print(pi_hat)
```

3.056

#implementation 3

```
import numpy as np
from time import time

np.random.seed(1234)
beg_time = time()
old_est = 0
n = 1
MC_N = 10**6

while True:
    x_i = np.random.uniform(0, 1) * 2 - 1
    y_i = np.random.uniform(0, 1) * 2 - 1
    t_i = np.sqrt(x_i**2+y_i**2)
    A_n = 4*(t_i<=1)

    new_est = ((n-1)/n)*old_est + (1/n)*A_n

    if(n>MC_N):
        break
    n = n+1
    old_est = new_est

end_time = time()

print(new_est)

## 3.1402048597951002

print('Time difference of ',end_time-beg_time, 'secs')

## Time difference of 17.473275184631348 secs
```

```
#convergence trajectory
```

```
import numpy as np
import matplotlib.pyplot as plt

np.random.seed(1234)
old_est = 0
n = 1
MC_N = 10**6
results = np.repeat(0,MC_N+1).astype('float')

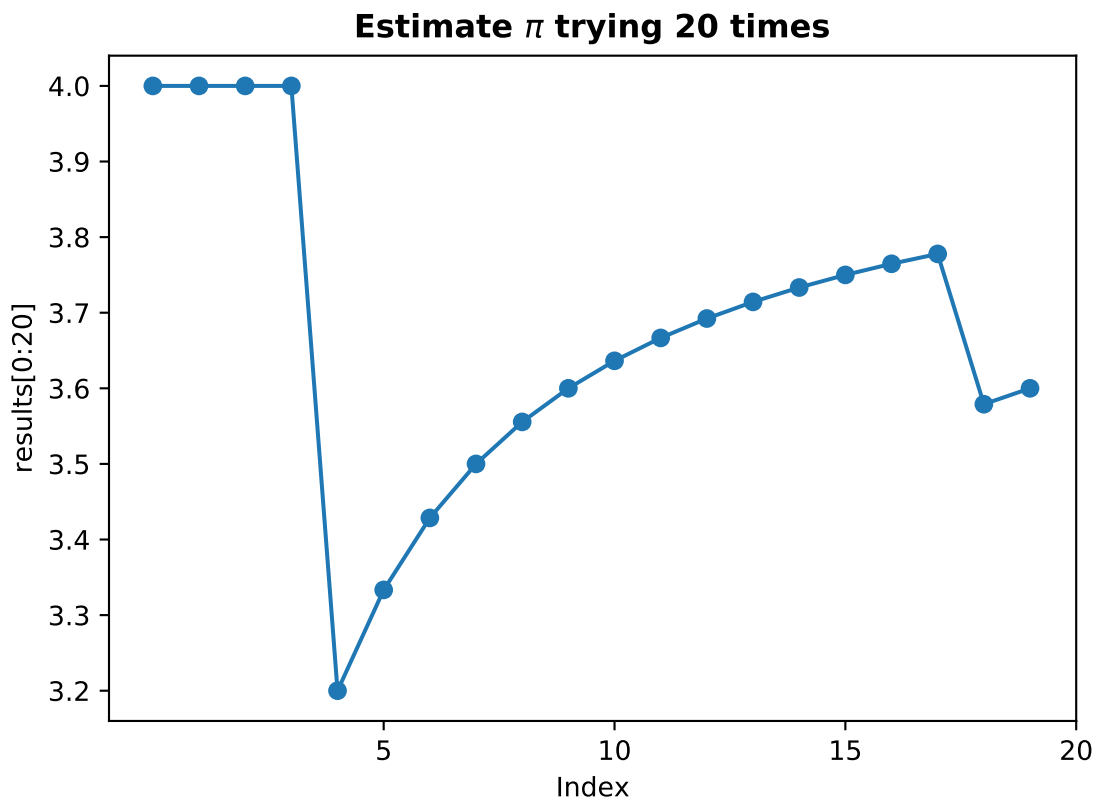
while True:
    x_i = np.random.uniform(0, 1) * 2 - 1
    y_i = np.random.uniform(0, 1) * 2 - 1
    t_i = np.sqrt(x_i**2+y_i**2)
    A_n = 4*(t_i<=1)

    new_est = ((n-1)/n)*old_est + (1/n)*A_n
    results[n] = new_est
    if(n>=MC_N):
        break
    n = n+1
    old_est = new_est

plt.plot(results[1:21],marker='o')
plt.title('Estimate '+r'$\pi$'+ ' trying 20 times',fontweight='bold')
plt.xlabel('Index')
plt.ylabel('results[0:20]')
plt.xticks([5,10,15,20])
```

```
## ([<matplotlib.axis.XTick object at 0x0000000025C52DD8>, <matplotlib.axis.XTick object at 0x0000000025C52DD8>],
```

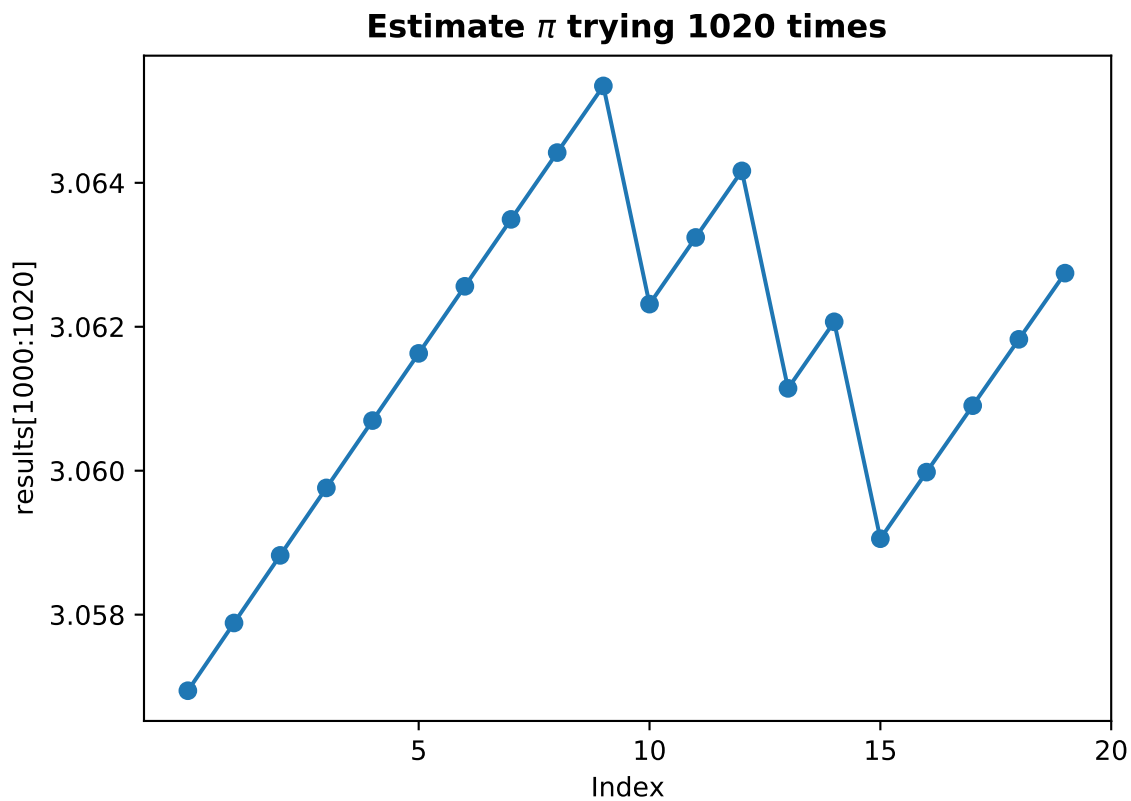
```
plt.show())
```



```
plt.plot(results[1001:1021],marker='o')
plt.title('Estimate '+r'$\pi$'+ ' trying 1020 times',fontweight='bold')
plt.xlabel('Index')
plt.ylabel('results[1000:1020]')
plt.xticks([5,10,15,20])
```

```
## ([<matplotlib.axis.XTick object at 0x000000002C7919E8>, <matplotlib.axis.XTick object at 0x000000002C7919E8>],
```

```
plt.show()
```



```
plt.plot(results[100000:100021],marker='o')
ax=plt.gca()
ax.get_yaxis().get_major_formatter().set_useOffset(False)
plt.title('Estimate '+r'$\pi$'+ ' trying 100020 times',fontweight='bold')
plt.xlabel('Index')
plt.ylabel('results[100000:100020]')
plt.xticks([5,10,15,20])
```

```
## ([<matplotlib.axis.XTick object at 0x00000000427DAE48>, <matplotlib.axis.XTick object at 0x00000000427DAE48>],
```

```
plt.show()
```

