1 Homework 1

1.1 Exercise demo

Implement Fisher-Yates shuffle algorithm (https://en.wikipedia.org/wiki/Fisher%E2%80%93Yates_shuffle (https://en.wikipedia.org/wiki/Fisher%E2%80%93Yates_shuffle)) and measure how the performance scales as the number of cards being shuffled increases. Create a plot to show the result. You can just use a different integer for each unique card and no need to implement a card class by yourself.

1.2 Solution

I will base my solution on pseudocode from https://en.wikipedia.org/wiki/Fisher%E2%80%93Yates_shuffle (https://en.wikipedia.org/wiki/Fisher%E2%80%93Yates_shuffle).

For benchmarking I look at input sizes of length 2^0 to 2^{19}, testing powers of two. At every experiment size (n), the experiment is run 5 times and then results are averaged.

In [1]:

```python
from random import randint

def card_deck_generator(n: int) -> list:
    """
    Generates a deck of cards with n elements
    """
    cards = []
    for card in range(n):
        # Add plus 1, since I want the cards to start from 1
        cards.append(f'{card+1}')

    return cards
```

In [2]:

```python
def fisher_yates_shuffle(deck: list) -> list:
    """
    Creates a new list that is shuffled using Fisher-Yates shuffle algorithm.
    """
    shuffled_deck = deck[:]
    card_deck_length = len(shuffled_deck)
    for i in range(card_deck_length-1, 0, -1):
        j = randint(0, i)
        shuffled_deck[j], shuffled_deck[i] = shuffled_deck[i], shuffled_deck[j]

    return shuffled_deck


```

In [3]:

```
# Quick tests! Make sure to test your code.
# card_deck = card_deck_generator(n=100)
# fisher_yates_shuffle(card_deck) # Seems to work!
```

In [4]:

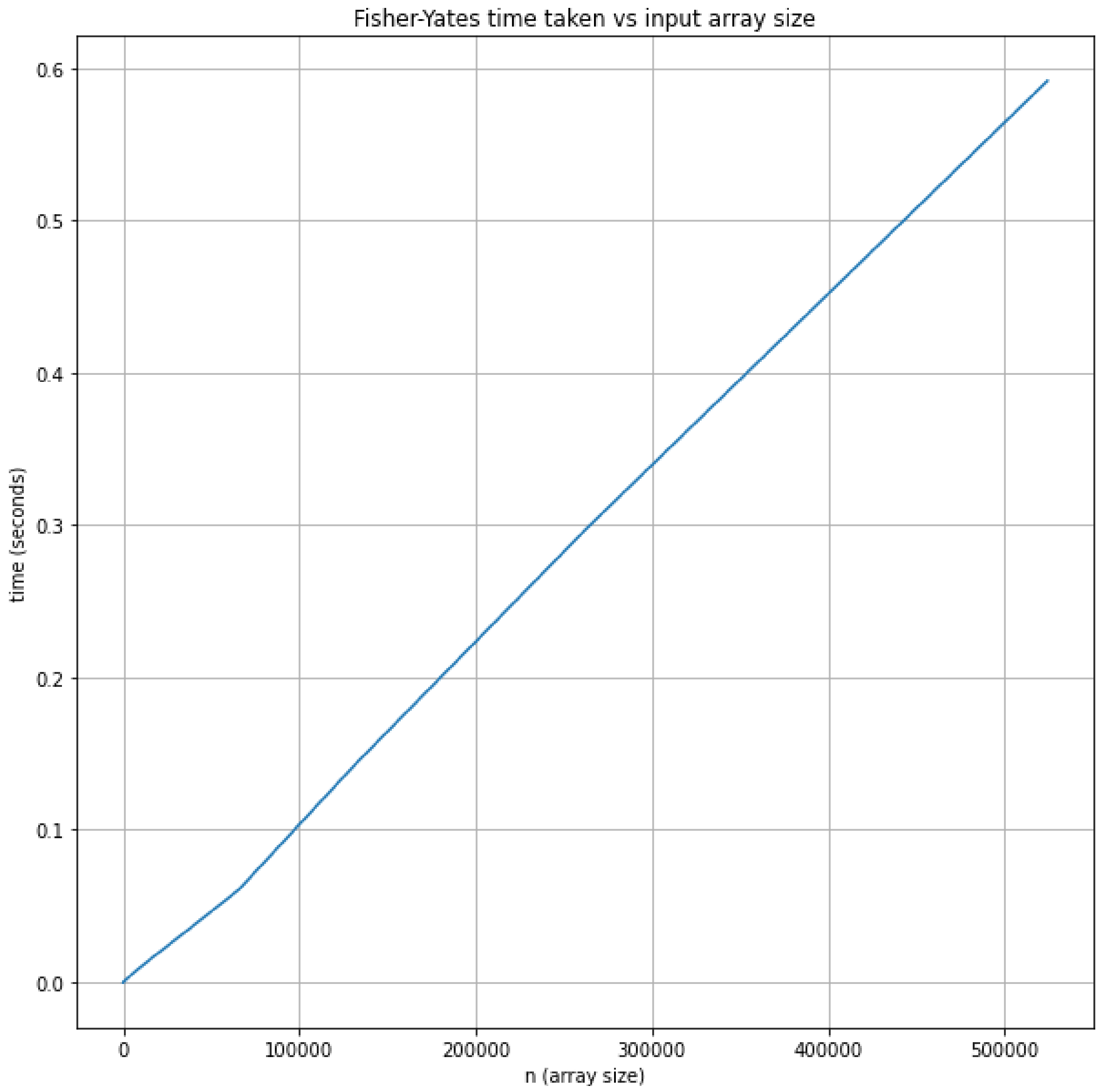
```
from time import monotonic
def benchmark_fy(n_ranges: list, n_attempts: int=1) -> list:
    """
    Benchmark Fisher-Yates algorithm.
    n_ranges: Sizes of array to use for experiment
    n_attempts: how many attempts to do for each n.
    """
    timings = []

    for n in n_ranges:
        # We do not want to include generation of data within timing procedure!
        n_times = []
        for _ in range(n_attempts):
            start_deck = card_deck_generator(n)
            start = monotonic()
            shuffled_deck = fisher_yates_shuffle(start_deck)
            end = monotonic()
            # Time taken (in seconds) is end - start
            n_times.append(end-start)

        # Add average time taken over n attempts as the result
        timings.append(sum(n_times)/n_attempts)

    return timings
```

In [5]:

```
# Generate 2-power input params for benchmark
experiment_n = [2**i for i in range(20)]

benchmark_results = benchmark_fy(
    n_ranges=experiment_n,
    n_attempts=5
)
```

In [6]:

```python
import matplotlib.pyplot as plt
plt.rcParams["figure.figsize"] = (10,10)

plt.plot(experiment_n, benchmark_results)
plt.grid(True)
plt.xlabel('n (array size)')
plt.ylabel('time (seconds)')
plt.title('Fisher-Yates time taken vs input array size')

plt.show()
```



1.2.1 Interpretation of results

As we can see from the plot above, we have linear scaling between input size and time taken to shuffle it. From the graph above, we can see that it takes approximately 0.2 seconds to shuffle an array of size 200 000 elements and 0.4 seconds to shuffle an array of length 400 000.

From the plot, I would say this algorithm belongs to big-O class of $O(n)$.