Statistical Analysis of Edmonds Karp and Ford Flukerson Running Times

All these numbers were obtained running on an Intel i3-5005U CPU @ 2.0 GHz running on the same 100 test cases for each algorithm

In [1]:
```
# read data
ford_flukerson = [] # data for ford flukerson
with open("FordFlukerson.txt") as text:
    ford_flukerson = [line.split(',') for line in text]
edmonds_karp = []
with open("EdmonsKarp.txt") as text:
    edmonds_karp = [line.split(',') for line in text]
# make data integers
for i in range(len(ford_flukerson)):
    for j in range(len(ford_flukerson[i])):
        ford_flukerson[i][j] = ford_flukerson[i][j].rstrip('\n')
        ford_flukerson[i][j] = int(ford_flukerson[i][j])
        edmonds_karp[i][j] = edmonds_karp[i][j].rstrip('\n')
        edmonds_karp[i][j] = int(edmonds_karp[i][j])
```

Performance comparison

In [2]:
```
total_ford = 0
for line in ford_flukerson:
    total_ford += line[3]
total_edmonds = 0
for line in edmonds_karp:
    total_edmonds += line[3]
print(
    "Total time for ford flukerson is " + str(total_ford) + " milliseconds, which is "
    + str(total_ford/(1000*60*60)) + " hours.")
print(
    "Total time for edmonds karo is " + str(total_edmonds) + " milliseconds, which is "
    + str(total_edmonds/(1000)) + " seconds.")
```

```
Total time for ford flukerson is 74524494 milliseconds, which is 20.701248333333332 hour
s.
Total time for edmonds karo is 56315 milliseconds, which is 56.315 seconds.
```

In [3]:
```
total_ford/total_edmonds
```

Out[3]:
```
1323.3506880937584
```

From the above we deduce that ford flukerson is more than 1300 times slower than edmonds karp.

Performance difference on each test case

In [4]:
```
ctr_edmonds = 0
ctr_ford = 0
ctr_same = 0
for i in range(len(ford_flukerson)):
    print("================================================================")
    print("Test#" + str(i + 1))
```

```
    print("Number of nodes: " + str(ford_flukerson[i][0]))
    print("Number of edges: " + str(ford_flukerson[i][1]))
    print("Max Flow: " + str(ford_flukerson[i][2]))
    print("Time took by ford flukerson: " + str(ford_flukerson[i][3]))
    print("Time took by edmonds karp: " + str(edmonds_karp[i][3]))
    if ford_flukerson[i][3] < edmonds_karp[i][3]:
        ctr_ford += 1
    elif ford_flukerson[i][3] > edmonds_karp[i][3]:
        ctr_edmonds += 1
    else:
        ctr_same += 1
    print("======================================================================")
```

```
======================================================================
Test#1
Number of nodes: 292
Number of edges: 42296
Max Flow: 7551533
Time took by ford flukerson: 2595346
Time took by edmonds karp: 983
======================================================================
======================================================================
Test#2
Number of nodes: 374
Number of edges: 18946
Max Flow: 1710813
Time took by ford flukerson: 383112
Time took by edmonds karp: 213
======================================================================
======================================================================
Test#3
Number of nodes: 32
Number of edges: 35775
Max Flow: 53269950
Time took by ford flukerson: 18821
Time took by edmonds karp: 2600
======================================================================
======================================================================
Test#4
Number of nodes: 319
Number of edges: 14722
Max Flow: 2496153
Time took by ford flukerson: 350001
Time took by edmonds karp: 96
======================================================================
======================================================================
Test#5
Number of nodes: 351
Number of edges: 8508
Max Flow: 1343485
Time took by ford flukerson: 155305
Time took by edmonds karp: 43
======================================================================
======================================================================
Test#6
Number of nodes: 257
Number of edges: 32405
Max Flow: 6216967
Time took by ford flukerson: 1492679
Time took by edmonds karp: 468
======================================================================
======================================================================
Test#7
Number of nodes: 368
```

```
Number of edges: 29879
Max Flow: 4183913
Time took by ford flukerson: 1081498
Time took by edmonds karp: 496
================================================================
================================================================
Test#8
Number of nodes: 377
Number of edges: 42155
Max Flow: 5169099
Time took by ford flukerson: 2118126
Time took by edmonds karp: 623
================================================================
================================================================
Test#9
Number of nodes: 171
Number of edges: 12438
Max Flow: 4087840
Time took by ford flukerson: 123517
Time took by edmonds karp: 50
================================================================
================================================================
Test#10
Number of nodes: 106
Number of edges: 7791
Max Flow: 3621538
Time took by ford flukerson: 11048
Time took by edmonds karp: 30
================================================================
================================================================
Test#11
Number of nodes: 100
Number of edges: 30080
Max Flow: 14860593
Time took by ford flukerson: 186985
Time took by edmonds karp: 1473
================================================================
================================================================
Test#12
Number of nodes: 72
Number of edges: 5676
Max Flow: 3853918
Time took by ford flukerson: 2128
Time took by edmonds karp: 51
================================================================
================================================================
Test#13
Number of nodes: 52
Number of edges: 11429
Max Flow: 10036046
Time took by ford flukerson: 3133
Time took by edmonds karp: 133
================================================================
================================================================
Test#14
Number of nodes: 243
Number of edges: 46011
Max Flow: 9468701
Time took by ford flukerson: 3681020
Time took by edmonds karp: 733
================================================================
================================================================
Test#15
Number of nodes: 472
Number of edges: 7545
```

```
Max Flow: 461142
Time took by ford flukerson: 79830
Time took by edmonds karp: 20
================================================================
================================================================
Test#16
Number of nodes: 411
Number of edges: 43024
Max Flow: 4810117
Time took by ford flukerson: 2962709
Time took by edmonds karp: 220
================================================================
================================================================
Test#17
Number of nodes: 294
Number of edges: 7852
Max Flow: 1254953
Time took by ford flukerson: 99732
Time took by edmonds karp: 29
================================================================
================================================================
Test#18
Number of nodes: 339
Number of edges: 12610
Max Flow: 1278247
Time took by ford flukerson: 150920
Time took by edmonds karp: 24
================================================================
================================================================
Test#19
Number of nodes: 250
Number of edges: 47844
Max Flow: 8289874
Time took by ford flukerson: 2858696
Time took by edmonds karp: 996
================================================================
================================================================
Test#20
Number of nodes: 415
Number of edges: 10063
Max Flow: 1377622
Time took by ford flukerson: 225128
Time took by edmonds karp: 56
================================================================
================================================================
Test#21
Number of nodes: 420
Number of edges: 1117
Max Flow: 3994
Time took by ford flukerson: 0
Time took by edmonds karp: 0
================================================================
================================================================
Test#22
Number of nodes: 110
Number of edges: 36677
Max Flow: 15375424
Time took by ford flukerson: 291145
Time took by edmonds karp: 1091
================================================================
================================================================
Test#23
Number of nodes: 258
Number of edges: 36062
Max Flow: 6466940
```

```
Time took by ford flukerson: 1542134
Time took by edmonds karp: 469
================================================================
================================================================
Test#24
Number of nodes: 141
Number of edges: 44417
Max Flow: 14682472
Time took by ford flukerson: 1342594
Time took by edmonds karp: 973
================================================================
================================================================
Test#25
Number of nodes: 346
Number of edges: 12602
Max Flow: 1793164
Time took by ford flukerson: 276340
Time took by edmonds karp: 48
================================================================
================================================================
Test#26
Number of nodes: 445
Number of edges: 8226
Max Flow: 833501
Time took by ford flukerson: 114100
Time took by edmonds karp: 13
================================================================
================================================================
Test#27
Number of nodes: 84
Number of edges: 19531
Max Flow: 11318345
Time took by ford flukerson: 32084
Time took by edmonds karp: 299
================================================================
================================================================
Test#28
Number of nodes: 101
Number of edges: 47244
Max Flow: 22942730
Time took by ford flukerson: 768200
Time took by edmonds karp: 1809
================================================================
================================================================
Test#29
Number of nodes: 160
Number of edges: 29090
Max Flow: 9153164
Time took by ford flukerson: 444814
Time took by edmonds karp: 385
================================================================
================================================================
Test#30
Number of nodes: 92
Number of edges: 6839
Max Flow: 3443917
Time took by ford flukerson: 5730
Time took by edmonds karp: 48
================================================================
================================================================
Test#31
Number of nodes: 169
Number of edges: 25553
Max Flow: 7200214
Time took by ford flukerson: 458376
```

```
Time took by edmonds karp: 196
================================================================
================================================================
Test#32
Number of nodes: 219
Number of edges: 17907
Max Flow: 3561733
Time took by ford flukerson: 307818
Time took by edmonds karp: 56
================================================================
================================================================
Test#33
Number of nodes: 396
Number of edges: 12897
Max Flow: 1167579
Time took by ford flukerson: 150252
Time took by edmonds karp: 66
================================================================
================================================================
Test#34
Number of nodes: 98
Number of edges: 46311
Max Flow: 22415557
Time took by ford flukerson: 465946
Time took by edmonds karp: 3325
================================================================
================================================================
Test#35
Number of nodes: 137
Number of edges: 36107
Max Flow: 11900558
Time took by ford flukerson: 475420
Time took by edmonds karp: 410
================================================================
================================================================
Test#36
Number of nodes: 234
Number of edges: 45357
Max Flow: 9469420
Time took by ford flukerson: 2432396
Time took by edmonds karp: 846
================================================================
================================================================
Test#37
Number of nodes: 218
Number of edges: 38183
Max Flow: 8787699
Time took by ford flukerson: 1759380
Time took by edmonds karp: 798
================================================================
================================================================
Test#38
Number of nodes: 173
Number of edges: 39120
Max Flow: 10076362
Time took by ford flukerson: 983030
Time took by edmonds karp: 956
================================================================
================================================================
Test#39
Number of nodes: 206
Number of edges: 489
Max Flow: 70450
Time took by ford flukerson: 43
Time took by edmonds karp: 0
```

```
================================================================
================================================================
Test#40
Number of nodes: 257
Number of edges: 34255
Max Flow: 6239594
Time took by ford flukerson: 1384291
Time took by edmonds karp: 564
================================================================
================================================================
Test#41
Number of nodes: 471
Number of edges: 9586
Max Flow: 880325
Time took by ford flukerson: 146568
Time took by edmonds karp: 62
================================================================
================================================================
Test#42
Number of nodes: 161
Number of edges: 40025
Max Flow: 11593045
Time took by ford flukerson: 1004592
Time took by edmonds karp: 817
================================================================
================================================================
Test#43
Number of nodes: 143
Number of edges: 6487
Max Flow: 2045388
Time took by ford flukerson: 15870
Time took by edmonds karp: 43
================================================================
================================================================
Test#44
Number of nodes: 181
Number of edges: 32926
Max Flow: 8696594
Time took by ford flukerson: 979586
Time took by edmonds karp: 645
================================================================
================================================================
Test#45
Number of nodes: 12
Number of edges: 9287
Max Flow: 35255963
Time took by ford flukerson: 548
Time took by edmonds karp: 215
================================================================
================================================================
Test#46
Number of nodes: 326
Number of edges: 42415
Max Flow: 5806051
Time took by ford flukerson: 1799978
Time took by edmonds karp: 273
================================================================
================================================================
Test#47
Number of nodes: 34
Number of edges: 17443
Max Flow: 21817709
Time took by ford flukerson: 5403
Time took by edmonds karp: 446
================================================================
```

```
================================================================
Test#48
Number of nodes: 355
Number of edges: 23773
Max Flow: 2661820
Time took by ford flukerson: 427738
Time took by edmonds karp: 84
================================================================
================================================================
Test#49
Number of nodes: 321
Number of edges: 29221
Max Flow: 3975644
Time took by ford flukerson: 944826
Time took by edmonds karp: 277
================================================================
================================================================
Test#50
Number of nodes: 159
Number of edges: 43340
Max Flow: 14165346
Time took by ford flukerson: 1537592
Time took by edmonds karp: 1327
================================================================
================================================================
Test#51
Number of nodes: 226
Number of edges: 34477
Max Flow: 7362445
Time took by ford flukerson: 1369338
Time took by edmonds karp: 390
================================================================
================================================================
Test#52
Number of nodes: 464
Number of edges: 39721
Max Flow: 4124478
Time took by ford flukerson: 1874327
Time took by edmonds karp: 404
================================================================
================================================================
Test#53
Number of nodes: 350
Number of edges: 30586
Max Flow: 3838285
Time took by ford flukerson: 1066497
Time took by edmonds karp: 328
================================================================
================================================================
Test#54
Number of nodes: 62
Number of edges: 14438
Max Flow: 12284011
Time took by ford flukerson: 10013
Time took by edmonds karp: 180
================================================================
================================================================
Test#55
Number of nodes: 260
Number of edges: 33251
Max Flow: 6312124
Time took by ford flukerson: 1132808
Time took by edmonds karp: 299
================================================================
================================================================
```

```
Test#56
Number of nodes: 31
Number of edges: 18473
Max Flow: 28356847
Time took by ford flukerson: 5760
Time took by edmonds karp: 457
================================================================
================================================================
Test#57
Number of nodes: 72
Number of edges: 43328
Max Flow: 30238887
Time took by ford flukerson: 151733
Time took by edmonds karp: 1568
================================================================
================================================================
Test#58
Number of nodes: 402
Number of edges: 20477
Max Flow: 2807420
Time took by ford flukerson: 651805
Time took by edmonds karp: 136
================================================================
================================================================
Test#59
Number of nodes: 463
Number of edges: 23736
Max Flow: 2073432
Time took by ford flukerson: 572731
Time took by edmonds karp: 357
================================================================
================================================================
Test#60
Number of nodes: 378
Number of edges: 41991
Max Flow: 4534610
Time took by ford flukerson: 1466819
Time took by edmonds karp: 218
================================================================
================================================================
Test#61
Number of nodes: 304
Number of edges: 49741
Max Flow: 7287019
Time took by ford flukerson: 3282942
Time took by edmonds karp: 814
================================================================
================================================================
Test#62
Number of nodes: 140
Number of edges: 9925
Max Flow: 2761396
Time took by ford flukerson: 32369
Time took by edmonds karp: 25
================================================================
================================================================
Test#63
Number of nodes: 312
Number of edges: 30871
Max Flow: 5477114
Time took by ford flukerson: 1276601
Time took by edmonds karp: 178
================================================================
================================================================
Test#64
```

```
Number of nodes: 330
Number of edges: 35839
Max Flow: 5036102
Time took by ford flukerson: 1718302
Time took by edmonds karp: 300
================================================================
================================================================
Test#65
Number of nodes: 440
Number of edges: 30334
Max Flow: 3421107
Time took by ford flukerson: 1045253
Time took by edmonds karp: 304
================================================================
================================================================
Test#66
Number of nodes: 90
Number of edges: 16717
Max Flow: 8875038
Time took by ford flukerson: 28177
Time took by edmonds karp: 316
================================================================
================================================================
Test#67
Number of nodes: 221
Number of edges: 34811
Max Flow: 8418148
Time took by ford flukerson: 1517187
Time took by edmonds karp: 390
================================================================
================================================================
Test#68
Number of nodes: 345
Number of edges: 2675
Max Flow: 225792
Time took by ford flukerson: 17435
Time took by edmonds karp: 3
================================================================
================================================================
Test#69
Number of nodes: 93
Number of edges: 18000
Max Flow: 9892693
Time took by ford flukerson: 45933
Time took by edmonds karp: 219
================================================================
================================================================
Test#70
Number of nodes: 470
Number of edges: 8713
Max Flow: 736191
Time took by ford flukerson: 119336
Time took by edmonds karp: 9
================================================================
================================================================
Test#71
Number of nodes: 148
Number of edges: 32111
Max Flow: 9716799
Time took by ford flukerson: 553088
Time took by edmonds karp: 307
================================================================
================================================================
Test#72
Number of nodes: 466
```

```
Number of edges: 1760
Max Flow: 384752
Time took by ford flukerson: 29649
Time took by edmonds karp: 2
================================================================
================================================================
Test#73
Number of nodes: 23
Number of edges: 34793
Max Flow: 71859298
Time took by ford flukerson: 12442
Time took by edmonds karp: 2108
================================================================
================================================================
Test#74
Number of nodes: 485
Number of edges: 17392
Max Flow: 1206775
Time took by ford flukerson: 301455
Time took by edmonds karp: 73
================================================================
================================================================
Test#75
Number of nodes: 133
Number of edges: 45465
Max Flow: 17191918
Time took by ford flukerson: 1004602
Time took by edmonds karp: 3004
================================================================
================================================================
Test#76
Number of nodes: 350
Number of edges: 1820
Max Flow: 337436
Time took by ford flukerson: 13742
Time took by edmonds karp: 3
================================================================
================================================================
Test#77
Number of nodes: 414
Number of edges: 7476
Max Flow: 897963
Time took by ford flukerson: 115653
Time took by edmonds karp: 21
================================================================
================================================================
Test#78
Number of nodes: 47
Number of edges: 23039
Max Flow: 22932228
Time took by ford flukerson: 16584
Time took by edmonds karp: 877
================================================================
================================================================
Test#79
Number of nodes: 43
Number of edges: 43235
Max Flow: 46906083
Time took by ford flukerson: 43872
Time took by edmonds karp: 3235
================================================================
================================================================
Test#80
Number of nodes: 175
Number of edges: 2090
```

```
Max Flow: 562423
Time took by ford flukerson: 5600
Time took by edmonds karp: 3
================================================================
================================================================
Test#81
Number of nodes: 308
Number of edges: 26710
Max Flow: 4069987
Time took by ford flukerson: 913478
Time took by edmonds karp: 249
================================================================
================================================================
Test#82
Number of nodes: 455
Number of edges: 2412
Max Flow: 305958
Time took by ford flukerson: 24229
Time took by edmonds karp: 3
================================================================
================================================================
Test#83
Number of nodes: 104
Number of edges: 9972
Max Flow: 3824197
Time took by ford flukerson: 11027
Time took by edmonds karp: 139
================================================================
================================================================
Test#84
Number of nodes: 86
Number of edges: 26824
Max Flow: 15617901
Time took by ford flukerson: 87856
Time took by edmonds karp: 802
================================================================
================================================================
Test#85
Number of nodes: 485
Number of edges: 19804
Max Flow: 1663186
Time took by ford flukerson: 473005
Time took by edmonds karp: 109
================================================================
================================================================
Test#86
Number of nodes: 422
Number of edges: 9659
Max Flow: 607093
Time took by ford flukerson: 97395
Time took by edmonds karp: 30
================================================================
================================================================
Test#87
Number of nodes: 481
Number of edges: 48894
Max Flow: 4909696
Time took by ford flukerson: 3037768
Time took by edmonds karp: 429
================================================================
================================================================
Test#88
Number of nodes: 31
Number of edges: 49926
Max Flow: 77292152
```

```
Time took by ford flukerson: 42678
Time took by edmonds karp: 3607
================================================================
================================================================
Test#89
Number of nodes: 327
Number of edges: 17140
Max Flow: 2486568
Time took by ford flukerson: 362296
Time took by edmonds karp: 95
================================================================
================================================================
Test#90
Number of nodes: 149
Number of edges: 44473
Max Flow: 13383762
Time took by ford flukerson: 1124583
Time took by edmonds karp: 1340
================================================================
================================================================
Test#91
Number of nodes: 246
Number of edges: 43861
Max Flow: 8397805
Time took by ford flukerson: 2305761
Time took by edmonds karp: 509
================================================================
================================================================
Test#92
Number of nodes: 176
Number of edges: 41512
Max Flow: 10485570
Time took by ford flukerson: 1122195
Time took by edmonds karp: 711
================================================================
================================================================
Test#93
Number of nodes: 426
Number of edges: 12165
Max Flow: 1125359
Time took by ford flukerson: 215421
Time took by edmonds karp: 74
================================================================
================================================================
Test#94
Number of nodes: 52
Number of edges: 47148
Max Flow: 42140834
Time took by ford flukerson: 84923
Time took by edmonds karp: 1926
================================================================
================================================================
Test#95
Number of nodes: 93
Number of edges: 29234
Max Flow: 13871779
Time took by ford flukerson: 101323
Time took by edmonds karp: 731
================================================================
================================================================
Test#96
Number of nodes: 254
Number of edges: 34385
Max Flow: 7077528
Time took by ford flukerson: 1586589
```

```
Time took by edmonds karp: 285
================================================================
================================================================
Test#97
Number of nodes: 166
Number of edges: 41016
Max Flow: 12648466
Time took by ford flukerson: 1822960
Time took by edmonds karp: 667
================================================================
================================================================
Test#98
Number of nodes: 59
Number of edges: 45772
Max Flow: 37011565
Time took by ford flukerson: 130019
Time took by edmonds karp: 1760
================================================================
================================================================
Test#99
Number of nodes: 343
Number of edges: 16972
Max Flow: 2182652
Time took by ford flukerson: 482920
Time took by edmonds karp: 51
================================================================
================================================================
Test#100
Number of nodes: 414
Number of edges: 44505
Max Flow: 4537663
Time took by ford flukerson: 2339487
Time took by edmonds karp: 392
================================================================
```

In [5]:
```
print("Number of times edmonds karp is faster: " + str(ctr_edmonds))
print("Number of times ford flukerson is faster: " + str(ctr_ford))
print("Number of times both had the same performance: " + str(ctr_same))
```

```
Number of times edmonds karp is faster: 99
Number of times ford flukerson is faster: 0
Number of times both had the same performance: 1
```

In [6]:
```
print("Percentage of tests edmonds karp is faster: " + str(ctr_edmonds) + "%")
print("Percentage of tests ford flukerson is faster: " + str(ctr_ford) + "%")
print("Percentage of tests both had the same performance: " + str(ctr_same) + "%")
```

```
Percentage of tests edmonds karp is faster: 99%
Percentage of tests ford flukerson is faster: 0%
Percentage of tests both had the same performance: 1%
```

The fastest time that ford flukerson performed was on test 21 where both of them finished the algorithm nearly instantaneously. If we take a closer look at that test case below

Test 21

Number of nodes: 420

Number of edges: 1117

Max Flow: 3994

Time took by ford flukerson: 0

Time took by edmonds karp: 0

we see that despite having a large number of nodes which is near the max number of nodes (500) It has a small max flow (less than 10^5)

Pearson Corellation between Big O Notation and real running time

First we need to get the data ready to calculate the correlation

In [7]:
```
from scipy.stats import pearsonr
```

In [8]:
```
time = []
bigo = []
```

In [9]:
```
# Ford Flukerson runs in O(V * MAX_FLOW)
for line in ford_flukerson:
    bigo.append(line[0] * line[2])
    time.append(line[3])
corr, _ = pearsonr(time, bigo)
corr
```

Out[9]:
```
0.6874639105529642
```

In [10]:
```
time = []
bigo = []
# Edmonds Karp runs in O(V * E**2)
for line in edmonds_karp:
    bigo.append(line[0] * (line[1]**2))
    time.append(line[3])
corr, _ = pearsonr(time, bigo)
corr
```

Out[10]:
```
0.08992023564403337
```

From the above we see that both of them exibit a positive correlation which enforces the mathematical analysis of the running times.