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03: Časovna kompleksnost algoritmov

1 Uvod

Pri razvoju algoritmov in novih rešitev pogosto srečamo več možnih rešitev istega problema, pri čemer želimo postaviti neke kriterije za izbiro optimalne rešitve pri podanih zahtevah. Pogosto vključimo kriterij vpliva izbrane rešitve na naš sistem v smislu:

* koliko spomina zahteva algoritem za delovanje?

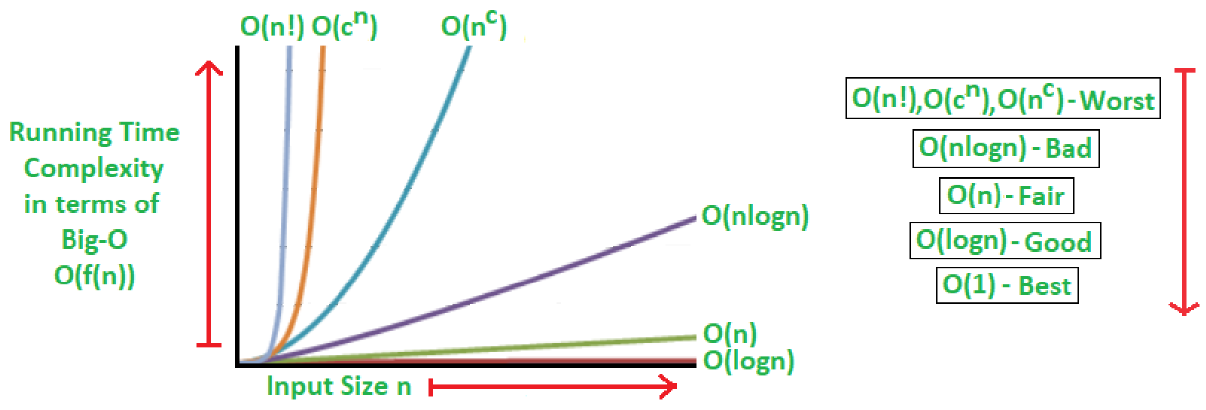
* koliko računskih operacij potrebuje za rešitev,

* koliko časa traja izvajanje (v sekundah ali ciklih procesorja).

Običajno nobena rešitev ali algoritem ne deluje optimalno po vseh teh kriterijih, saj bo hitrejši algoritem navadno potreboval več sistemskih resursov ali ciklov procesorja.

Pri nalogi se bomo osredotočili na merjenje časa, potrebnega za izvajanje različnih algoritmov sortiranja podatkov, in merjenje števila računskih operacij.

Razredi računske zahtevnosti so naslednji



Vir: https://www.geeksforgeeks.org/complete-guide-on-complexity-analysis/?ref=lbp

https://www.geeksforgeeks.org/time-complexities-of-all-sorting-algorithms/?ref=shm

2 Algoritem Fibonacci

Fibonaccijevo zaporedje števil je: 1, 1, 2, 3, 5, 8, .. seštejemo prejšnji dve števili.

2.1 Izpiši Fibonnacijevo zaporedje števil

za N od 1 do 20: Fibonacci for 10 execution time sec: 1.0839999995898921e-05

2.2 Merjenje časa izvajanja s timeit

Za pravilno meritev časa izvajanja bomo uporabljali funkcijo `timeit()`, namenjeno testiranju hitrosti manjših koščkov kode. Uporablja se na naslednji način, primer:

`t.timeit('quicksort(data)','from __main__ import data,quicksort', number = num)`

Prvi niz je ukaz, ki ga merimo, nato drugi niz definira importe oziroma knjižnice, nato pa še, kolikokrat želimo izvesti ta ukaz (večkrat je bolj zanesljiva meritev časa).

Testiraj in izmeri čas izvajanja Fibonnaci funkcije za različne N:

```
# Measure execution time :
fibNumber = 10
t_fib = t.timeit('FibonacciRec(fibNumber)','from __main__ import fibNumber,
FibonacciRec', number = 1)

print('Fibonnaci for ', fibNumber, ' execution time sec: ', t_fib)
```

Rezultati: N, čas

Fibonacci for 1 execution time sec: 9.149998732027598e-07

Fibonacci for 3 execution time sec: 1.520999830972869e-06

Fibonacci for 5 execution time sec: 1.7669999579084106e-06

Fibonacci for 7 execution time sec: 3.1489998946199194e-06

Fibonacci for 9 execution time sec: 6.672999916190747e-06

Fibonacci for 10 execution time sec: 8.879999768396374e-06

Fibonacci for 11 execution time sec: 1.3902999853598885e-05

Fibonacci for 12 execution time sec: 2.182400021411013e-05

Fibonacci for 13 execution time sec: 5.010900076740654e-05

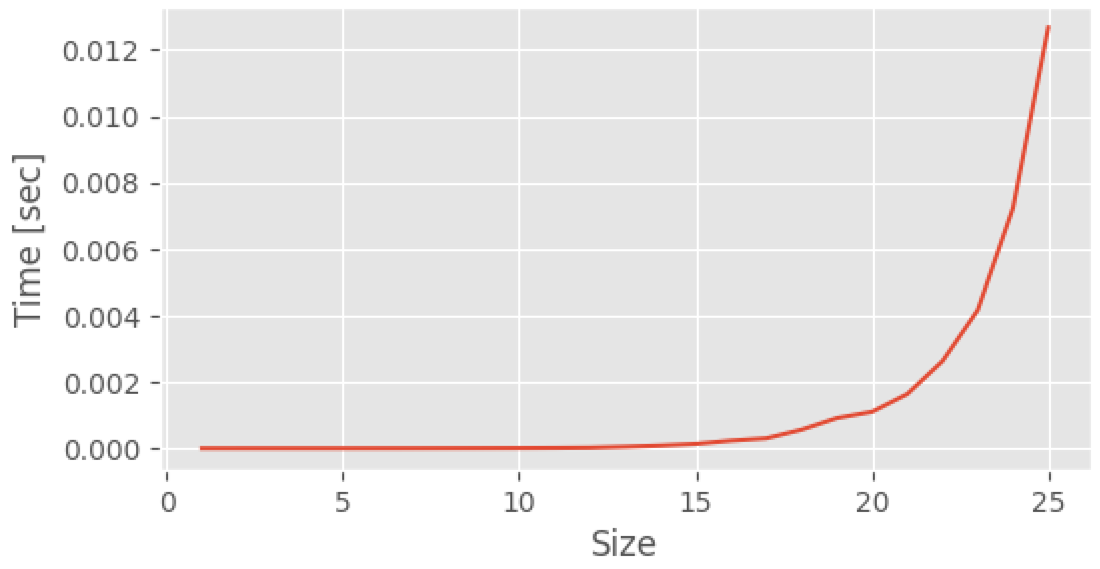
Fibonacci for 14 execution time sec: 8.518499998899642e-05

Fibonacci for 15 execution time sec: 0.00013424100005236161

```
Fibonacci for  16  execution time sec:  0.00023334300002181558
Fibonacci for  17  execution time sec:  0.0003043990000151098
Fibonacci for  18  execution time sec:  0.0005634109993479797
Fibonacci for  19  execution time sec:  0.0009134609999819077
Fibonacci for  20  execution time sec:  0.0011038320008083247
Fibonacci for  21  execution time sec:  0.0016381300001739874
Fibonacci for  22  execution time sec:  0.0026320930001020315
Fibonacci for  23  execution time sec:  0.004169587999967916
Fibonacci for  24  execution time sec:  0.00723394000033295
Fibonacci for  25  execution time sec:  0.012677415999860386
```

2.3 Izris grafa časov izvajanja

Izmeri čase za N v obsegu od 1 do 30, in izriši graf časa izvajanja v odvisnosti od N.



2.4 Razred Algorithm

Razred Algorithm omogoča merjenje časa in štetje operacij. Preuči kodo.

V kateri metodi razred testira čas izvajanja, kaj pomeni parameter? Katero metodo moramo definirati v izpeljanem razredu?

V metodi run

Testiraj razred, izvedi primer, kaj izpiše:

```
Algorithm.run_once, operations: 10 >> 0 , msec: 0.038 , operations: 10 Algorithm.run_once, operations: 10 >>
1 , msec: 0.008 , operations: 10 Algorithm.run_once, operations: 10 >> 2 , msec: 0.008 , operations: 10
Algorithm.run_once, operations: 10 >> 3 , msec: 0.008 , operations: 10 Algorithm.run_once, operations: 10 >>
4 , msec: 0.007 , operations: 10 >>> Algorithm > Total run() sec: 0.00016592299925832776 Avg iter msec:
0.03318459985166555
```

2.5 Primer uporabe za Fibonnaci algoritem

Preuči, kako smo definirali razred za testiranje Fibonnaci algoritma, katere metode ima?

Ime metode _init_ fibonnaciR in run_once

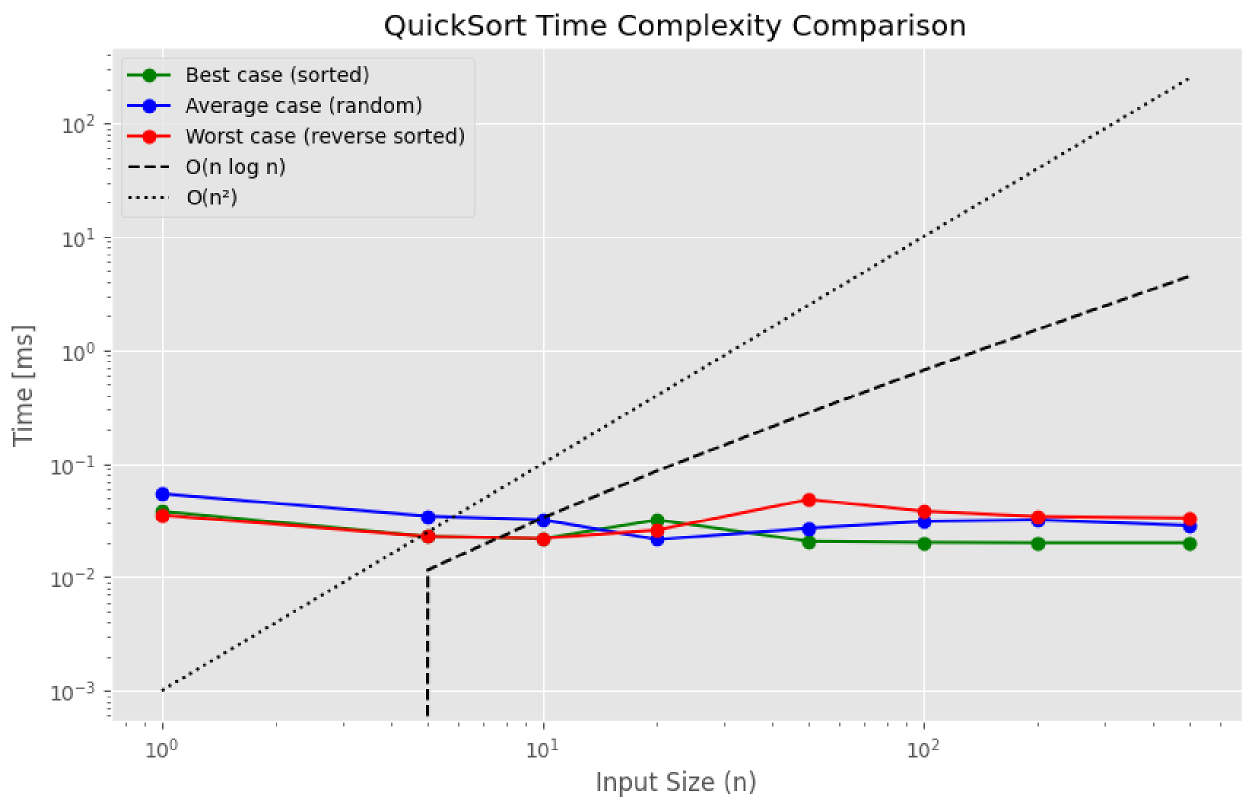
Kaj vsebuje rezultat testa?

```
>> 0 , msec: 0.033 , operations: 177 >> 1 , msec: 0.026 , operations: 177 >> 2 , msec: 0.022 , operations: 177
>> 3 , msec: 0.021 , operations: 177 >> 4 , msec: 0.021 , operations: 177 >> 5 , msec: 0.022 , operations: 177
>> 6 , msec: 0.021 , operations: 177 >> 7 , msec: 0.021 , operations: 177 >> 8 , msec: 0.021 , operations: 177
>> 9 , msec: 0.021 , operations: 177 >>> FibonacciRecursion > Total run() sec: 0.0005467689998113201 Avg
iter msec: 0.05467689998113201 Test result: {'name': 'FibonacciRecursion', 'avg_msec':
0.05467689998113201, 'avg_O': 177.0, 'niter': 10, 'output': 55} >> 0 , msec: 0.002 , operations: 0 >>>
QuickSort > Total run() sec: 3.7972999962221365e-05 Avg iter msec: 0.037972999962221365 N=1, Best case
(sorted): 0.0380ms >> 0 , msec: 0.001 , operations: 0 >>> QuickSort > Total run() sec: 2.284800029883627e-05
Avg iter msec: 0.02284800029883627 N=5, Best case (sorted): 0.0228ms >> 0 , msec: 0.001 , operations: 0 >>>
QuickSort > Total run() sec: 2.1840999579580966e-05 Avg iter msec: 0.021840999579580966 N=10, Best case
(sorted): 0.0218ms >> 0 , msec: 0.001 , operations: 0 >>> QuickSort > Total run() sec: 3.19500004479778e-05
Avg iter msec: 0.0319500004479778 N=20, Best case (sorted): 0.0320ms >> 0 , msec: 0.001 , operations: 0

...
N=200, Worst case (reverse sorted): 0.0342ms >> 0 , msec: 0.001 , operations: 0 >>> QuickSort > Total run()
sec: 3.3213000278919935e-05 Avg iter msec: 0.033213000278919935 N=500, Worst case (reverse sorted):
0.0332ms
```

2.6 Meritev operacij Fibonnaci rekurzivnega algoritma

Napiši kodo in izriši graf števila operacij za N od 1 do 30. Graf:



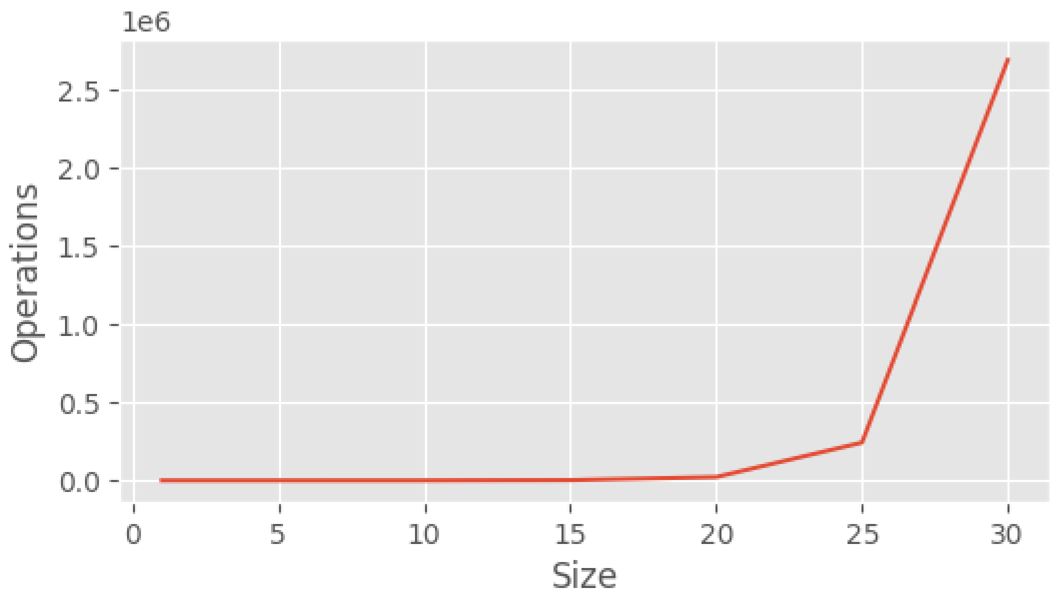
Vse tri grafe sem dodal v en graf.

Kakšen je razred računske zahtevnosti Fibonnaci rekurzivnega algoritma?

N^X

2.7 Meritev Fibonnaci algoritma brez rekurzije

Izriši graf in primerjaj zahtevnost s prejšnjo izvedbo (rekurzivno).



Kakšen je razred zahtevnosti tukaj, in primerjava z rekurzivno izvedbo?

2^n

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3 Algoritmi sortiranja

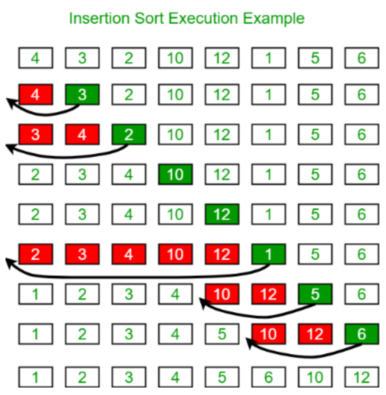
3.1 Kreiranje podatkovnega seta

Preizkusi funkcijo za ustvarjanje seznama števil, za različne tipe urejenosti števil. Izpiši in vstavi primere rezultatov (množica števil):

Type 1 (sorted ascending): [1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0] Type 2 (sorted descending): [10.0, 9.0, 8.0, 7.0, 6.0, 5.0, 4.0, 3.0, 2.0, 1.0] Type None (random): [5.4, 8.1, 3.0, 2.7, 4.9, 6.5, 4.9, 8.8, 7.3, 3.0]

3.2 Insertion sort

Osnovni algoritem sortiranja. Deluje s primerjavami parov števil (sosedov), in zamenja njihov vrstni red, če je prvi večji od drugega. Vrednosti števil iz neurejenega dela polja se prenesejo na ustrezno pozicijo v urejenem delu. Primer:



https://www.geeksforgeeks.org/insertion-sort/?ref=outind

https://en.wikipedia.org/wiki/Insertion_sort

3.3 Preizkusi funkcijo insertionSort2

Kreiraj podatke in jih izpiši. Uredi jih, ter izpiši rezultat.

Original data: [10.0, 9.0, 8.0, 7.0, 6.0, 5.0, 4.0, 3.0, 2.0, 1.0] Sorted data: [1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0]

3.4 Testiraj InsertionSort razred

Testiraj razred InsertionSort za različne tipe urejenosti podanih podatkov. Izpiši izhodne podatke in preveri, ali so urejeni.

>> 0 , msec: 86.647 , operations: 499500 >> 1 , msec: 69.778 , operations: 499500 >> 2 , msec: 71.835 , operations: 499500 >> 3 , msec: 69.908 , operations: 499500 >> 4 , msec: 72.286 , operations: 499500 >> 5 , msec: 76.741 , operations: 499500 >> 6 , msec: 72.250 , operations: 499500 >> 7 , msec: 73.172 , operations: 499500 >> 8 , msec: 72.575 , operations: 499500 >> 9 , msec: 72.694 , operations: 499500 >>> Insertion Sort > Total run() sec: 0.7390844199999265 Avg iter msec: 73.90844199999265 {'name': 'Insertion Sort', 'avg_msec': 73.90844199999265, 'avg_O': 499500.0, 'niter': 10, 'output': [1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0, 17.0, 18.0, 19.0, 20.0, 21.0, 22.0, 23.0, 24.0, 25.0, 26.0, 27.0, 28.0, 29.0, 30.0, 31.0, 32.0, 33.0, 34.0, 35.0, 36.0, 37.0, 38.0, 39.0, 40.0, 41.0, 42.0, 43.0, 44.0, 45.0, 46.0, 47.0, 48.0, 49.0, 50.0, 51.0, 52.0, 53.0, 54.0, 55.0, 56.0, 57.0, 58.0, 59.0, 60.0, 61.0, 62.0, 63.0, 64.0, 65.0, 66.0, 67.0, 68.0, 69.0, 70.0, 71.0, 72.0, 73.0, 74.0, 75.0, 76.0, 77.0, 78.0, 79.0, 80.0, 81.0, 82.0, 83.0, 84.0, 85.0, 86.0, 87.0, 88.0, 89.0, 90.0, 91.0, 92.0, 93.0, 94.0, 95.0, 96.0, 97.0, 98.0, 99.0, 100.0, 101.0, 102.0, 103.0, 104.0, 105.0, 106.0, 107.0, 108.0, 109.0, 110.0, 111.0, 112.0, 113.0, 114.0, 115.0, 116.0, 117.0, 118.0, 119.0, 120.0, 121.0, 122.0, 123.0, 124.0, 125.0, 126.0, 127.0, 128.0, 129.0, 130.0, 131.0, 132.0, 133.0, 134.0, 135.0, 136.0, 137.0, 138.0, 139.0, 140.0, 141.0, 142.0, 143.0, 144.0, 145.0, 146.0, 147.0, 148.0, 149.0, 150.0, 151.0, 152.0, 153.0, 154.0, 155.0,

156.0, 157.0, 158.0, 159.0, 160.0, 161.0, 162.0, 163.0, 164.0, 165.0, 166.0, 167.0, 168.0, 169.0, 170.0, 171.0, 172.0, 173.0, 174.0, 175.0, 176.0, 177.0, 178.0, 179.0, 180.0, 181.0, 182.0, 183.0, 184.0, 185.0, 186.0, 187.0, 188.0, 189.0, 190.0, 191.0, 192.0, 193.0, 194.0, 195.0, 196.0, 197.0, 198.0, 199.0, 200.0, 201.0, 202.0, 203.0, 204.0, 205.0, 206.0, 207.0, 208.0, 209.0, 210.0, 211.0, 212.0, 213.0, 214.0, 215.0, 216.0, 217.0, 218.0, 219.0, 220.0, 221.0, 222.0, 223.0, 224.0, 225.0, 226.0, 227.0, 228.0, 229.0, 230.0, 231.0, 232.0, 233.0, 234.0, 235.0, 236.0, 237.0, 238.0, 239.0, 240.0, 241.0, 242.0, 243.0, 244.0, 245.0, 246.0, 247.0, 248.0, 249.0, 250.0, 251.0, 252.0, 253.0, 254.0, 255.0, 256.0, 257.0, 258.0, 259.0, 260.0, 261.0, 262.0, 263.0, 264.0, 265.0, 266.0, 267.0, 268.0, 269.0, 270.0, 271.0, 272.0, 273.0, 274.0, 275.0, 276.0, 277.0, 278.0, 279.0, 280.0, 281.0, 282.0, 283.0, 284.0, 285.0, 286.0, 287.0, 288.0, 289.0, 290.0, 291.0, 292.0, 293.0, 294.0, 295.0, 296.0, 297.0, 298.0, 299.0, 300.0, 301.0, 302.0, 303.0, 304.0, 305.0, 306.0, 307.0, 308.0, 309.0, 310.0, 311.0, 312.0, 313.0, 314.0, 315.0, 316.0, 317.0, 318.0, 319.0, 320.0, 321.0, 322.0, 323.0, 324.0, 325.0, 326.0, 327.0, 328.0, 329.0, 330.0, 331.0, 332.0, 333.0, 334.0, 335.0, 336.0, 337.0, 338.0, 339.0, 340.0, 341.0, 342.0, 343.0, 344.0, 345.0, 346.0, 347.0, 348.0, 349.0, 350.0, 351.0, 352.0, 353.0, 354.0, 355.0, 356.0, 357.0, 358.0, 359.0, 360.0, 361.0, 362.0, 363.0, 364.0, 365.0, 366.0, 367.0, 368.0, 369.0, 370.0, 371.0, 372.0, 373.0, 374.0, 375.0, 376.0, 377.0, 378.0, 379.0, 380.0, 381.0, 382.0, 383.0, 384.0, 385.0, 386.0, 387.0, 388.0, 389.0, 390.0, 391.0, 392.0, 393.0, 394.0, 395.0, 396.0, 397.0, 398.0, 399.0, 400.0, 401.0, 402.0, 403.0, 404.0, 405.0, 406.0, 407.0, 408.0, 409.0, 410.0, 411.0, 412.0, 413.0, 414.0, 415.0, 416.0, 417.0, 418.0, 419.0, 420.0, 421.0, 422.0, 423.0, 424.0, 425.0, 426.0, 427.0, 428.0, 429.0, 430.0, 431.0, 432.0, 433.0, 434.0, 435.0, 436.0, 437.0, 438.0, 439.0, 440.0, 441.0, 442.0, 443.0, 444.0, 445.0, 446.0, 447.0, 448.0, 449.0, 450.0, 451.0, 452.0, 453.0, 454.0, 455.0, 456.0, 457.0, 458.0, 459.0, 460.0, 461.0, 462.0, 463.0, 464.0, 465.0, 466.0, 467.0, 468.0, 469.0, 470.0, 471.0, 472.0, 473.0, 474.0, 475.0, 476.0, 477.0, 478.0, 479.0, 480.0, 481.0, 482.0, 483.0, 484.0, 485.0, 486.0, 487.0, 488.0, 489.0, 490.0, 491.0, 492.0, 493.0, 494.0, 495.0, 496.0, 497.0, 498.0, 499.0, 500.0, 501.0, 502.0, 503.0, 504.0, 505.0, 506.0, 507.0, 508.0, 509.0, 510.0, 511.0, 512.0, 513.0, 514.0, 515.0, 516.0, 517.0, 518.0, 519.0, 520.0, 521.0, 522.0, 523.0, 524.0, 525.0, 526.0, 527.0, 528.0, 529.0, 530.0, 531.0, 532.0, 533.0, 534.0, 535.0, 536.0, 537.0, 538.0, 539.0, 540.0, 541.0, 542.0, 543.0, 544.0, 545.0, 546.0, 547.0, 548.0, 549.0, 550.0, 551.0, 552.0, 553.0, 554.0, 555.0, 556.0, 557.0, 558.0, 559.0, 560.0, 561.0, 562.0, 563.0, 564.0, 565.0, 566.0, 567.0, 568.0, 569.0, 570.0, 571.0, 572.0, 573.0, 574.0, 575.0, 576.0, 577.0, 578.0, 579.0, 580.0, 581.0, 582.0, 583.0, 584.0, 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728.0, 729.0, 730.0, 731.0, 732.0, 733.0, 734.0, 735.0, 736.0, 737.0, 738.0, 739.0, 740.0, 741.0, 742.0, 743.0, 744.0, 745.0, 746.0, 747.0, 748.0, 749.0, 750.0, 751.0, 752.0, 753.0, 754.0, 755.0, 756.0, 757.0, 758.0, 759.0, 760.0, 761.0, 762.0, 763.0, 764.0, 765.0, 766.0, 767.0, 768.0, 769.0, 770.0, 771.0, 772.0, 773.0, 774.0, 775.0, 776.0, 777.0, 778.0, 779.0, 780.0, 781.0, 782.0, 783.0, 784.0, 785.0, 786.0, 787.0, 788.0, 789.0, 790.0, 791.0, 792.0, 793.0, 794.0, 795.0, 796.0, 797.0, 798.0, 799.0, 800.0, 801.0, 802.0, 803.0, 804.0, 805.0, 806.0, 807.0, 808.0, 809.0, 810.0, 811.0, 812.0, 813.0, 814.0, 815.0, 816.0, 817.0, 818.0, 819.0, 820.0, 821.0, 822.0, 823.0, 824.0, 825.0, 826.0, 827.0, 828.0, 829.0, 830.0, 831.0, 832.0, 833.0, 834.0, 835.0, 836.0, 837.0, 838.0, 839.0, 840.0, 841.0, 842.0, 843.0, 844.0, 845.0, 846.0, 847.0, 848.0, 849.0, 850.0, 851.0, 852.0, 853.0, 854.0, 855.0, 856.0, 857.0, 858.0, 859.0, 860.0, 861.0, 862.0, 863.0, 864.0, 865.0, 866.0, 867.0, 868.0, 869.0, 870.0, 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```
892.0, 893.0, 894.0, 895.0, 896.0, 897.0, 898.0, 899.0, 900.0, 901.0, 902.0, 903.0, 904.0, 905.0, 906.0, 907.0,
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940.0, 941.0, 942.0, 943.0, 944.0, 945.0, 946.0, 947.0, 948.0, 949.0, 950.0, 951.0, 952.0, 953.0, 954.0, 955.0,
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800.0, 801.0, 802.0, 803.0, 804.0, 805.0, 806.0, 807.0, 808.0, 809.0, 810.0, 811.0, 812.0, 813.0, 814.0, 815.0,
816.0, 817.0, 818.0, 819.0, 820.0, 821.0, 822.0, 823.0, 824.0, 825.0, 826.0, 827.0, 828.0, 829.0, 830.0, 831.0,
832.0, 833.0, 834.0, 835.0, 836.0, 837.0, 838.0, 839.0, 840.0, 841.0, 842.0, 843.0, 844.0, 845.0, 846.0, 847.0,
848.0, 849.0, 850.0, 851.0, 852.0, 853.0, 854.0, 855.0, 856.0, 857.0, 858.0, 859.0, 860.0, 861.0, 862.0, 863.0,
864.0, 865.0, 866.0, 867.0, 868.0, 869.0, 870.0, 871.0, 872.0, 873.0, 874.0, 875.0, 876.0, 877.0, 878.0, 879.0,
880.0, 881.0, 882.0, 883.0, 884.0, 885.0, 886.0, 887.0, 888.0, 889.0, 890.0, 891.0, 892.0, 893.0, 894.0, 895.0,
896.0, 897.0, 898.0, 899.0, 900.0, 901.0, 902.0, 903.0, 904.0, 905.0, 906.0, 907.0, 908.0, 909.0, 910.0, 911.0,
912.0, 913.0, 914.0, 915.0, 916.0, 917.0, 918.0, 919.0, 920.0, 921.0, 922.0, 923.0, 924.0, 925.0, 926.0, 927.0,
928.0, 929.0, 930.0, 931.0, 932.0, 933.0, 934.0, 935.0, 936.0, 937.0, 938.0, 939.0, 940.0, 941.0, 942.0, 943.0,
944.0, 945.0, 946.0, 947.0, 948.0, 949.0, 950.0, 951.0, 952.0, 953.0, 954.0, 955.0, 956.0, 957.0, 958.0, 959.0,
960.0, 961.0, 962.0, 963.0, 964.0, 965.0, 966.0, 967.0, 968.0, 969.0, 970.0, 971.0, 972.0, 973.0, 974.0, 975.0,
976.0, 977.0, 978.0, 979.0, 980.0, 981.0, 982.0, 983.0, 984.0, 985.0, 986.0, 987.0, 988.0, 989.0, 990.0, 991.0,
992.0, 993.0, 994.0, 995.0, 996.0, 997.0, 998.0, 999.0, 1000.0]

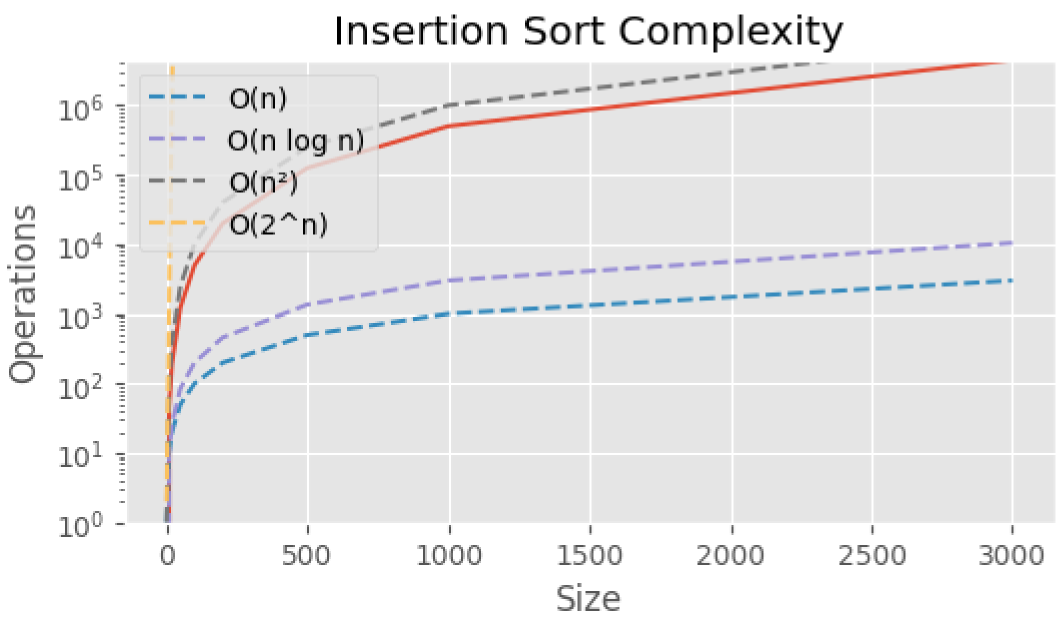
3.5 Ugotovi časovno kompleksnost Insertion sort algoritma

Napiši kodo, ki testira Insertion sort za različne velikosti podatkov in izriše graf.

```
n_list = [1,10,20,50,100, 200, 500, 1000,3000]
```

Za izris grafov lahko uporabiš namesto kode zgoraj pomožni razred AlgorithmBenchmark. Za yscale izberi ali log ali linear.

```
# Plot with new utilities
from utils import AlgorithmBenchmark
perf = AlgorithmBenchmark()
ref1 = perf.generate_reference_curves(n_list, num_curves=4)
perf.plot_complexity(n_list, oper_list, ref1, title='Insertion Sort Complexity',
ymax=max(oper_list), yscale='log')
```



Ocena časovne kompleksnosti Insertion sort algoritma:

O(n log n)

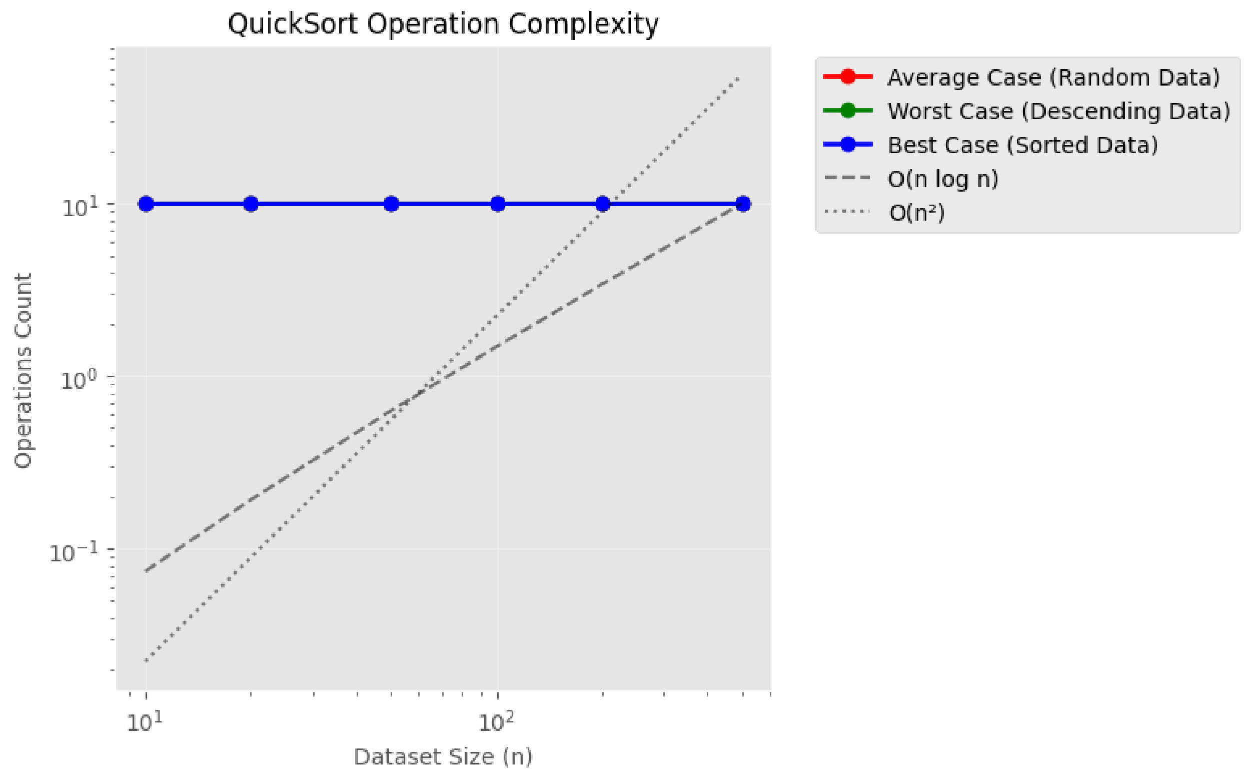
3.6 Quick Sort algoritem

https://www.geeksforgeeks.org/quick-sort/?ref=lbp

Temelji na principu divide and conquer, kar pomeni, da postopno deli podatke v manjše in manjše skupine, dokler niso urejeni. Izbere naključni element (pivot), ter nato uredi vse ostale podatke v dve skupini, manjše in večje od tega elementa. To urejanje ponavlja rekurzivno, dokler skupina ne vsebuje samo enega elementa.

https://en.wikipedia.org/wiki/Quicksort

Napiši kodo, ki testira Quick sort za različne velikosti podatkov in izriše graf.



Vsi trije grafi bi morali biti narisani na tem grafu, vendar mi je nekaj cudno prislo in mi ni uspelo jih izrisati na graf.

Časovna kompleksnost algoritma v različnih primerih podatkov?

Nisem uspel resiti, ker mi graf ni prisel prav.

Primerjava z Insertion Sort?

Nisem uspel primerjati, ker mi graf ni prisel prav.

3.7 Dodatna naloga: Analiziraj časovno kompleksnost Bubble sort algoritma

Algoritem in razlaga je tukaj:

https://www.geeksforgeeks.org/bubble-sort-algorithm/?ref=shm