Semesterarbeit Teil 1a

Aufgabe 1 und 2

```
fibonacci_count.py
```

Das Programm erwartet die Eingabe eines Integers max_fibonacci und berechnet dann die Fibonacci Zahlen von 0 bis zu dieser Obergrenze.

Für Aufgabe 2 wird die Anzahl Aufrufe der rekursiven Funktion fib(n) ausgegeben, welche zur Berechnung nötig war. Diese Anzahl wird über die globale Variable total_calls gezählt.

```
Fibonacci numbers for range 0 to 10
n: 0
       fib(n): 0 total_calls:
       fib(n): 1 total_calls:
n: 1
                               1
       fib(n): 1 total_calls:
n: 2
                              3
n: 3 fib(n): 2 total_calls: 5
n: 4
       fib(n): 3 total_calls:
                             9
n: 5 fib(n): 5 total_calls: 15
       fib(n): 8 total_calls: 25
n: 6
n: 7 fib(n): 13 total_calls: 41
n: 8 fib(n): 21 total_calls: 67
n: 9
      fib(n): 34 total calls: 109
n: 10 fib(n): 55
                   total_calls: 177
```

Aufgabe 3

Die Anzahl Funktionsaufrufe ergibt diese Folge:

```
1, 3, 5, 9, 15, 25, 41, 67, 109, 177, ...
```

Gegenüberstellung Anzahl Funktionsaufrufe mit Fibonacci Zahlen:

```
Funktionsaufrufe: 1 1 3 5 9 15 25 41 67 109 177
Fibonacci Zahl: 0 1 1 2 3 5 8 13 21 34 55
```

Vermutung für die Anzahl Funktionsaufrufe total_calls zur Berechnung der n-ten Fibonacci Zahl:

```
total_calls = 2 * fib(n + 1) - 1
```

Benötigt also selbst wieder die Fibonacci Funktion.

Aufgabe 4

```
fibonacci_time.py
```

```
fibonacci module.py
```

Funktion fib(n) jetzt in separatem Modul untergebracht. Gleich wie erste Implementierung, aber ohne globalen Zähler (wegen Einfluss auf Zeitmessung).

Das Programm fibonacci_time.py ruft fib(n) auf und gibt die gemessenen Zeiten aus. Das sieht nach exponentiellem Wachstum für die "elapsed seconds" aus.

```
Fibonacci numbers for range 0 to 40
n:
     0
          fib(n):
                            0
                                 elapsed seconds: 0.0
     1
          fib(n):
                            1
                                 elapsed seconds: 0.0
n:
     2
          fib(n):
                            1
                                 elapsed seconds: 0.0
                            2
     3
          fib(n):
                                 elapsed seconds: 0.0
n:
     4
          fib(n):
                            3
                                 elapsed seconds: 0.0
n:
     5
          fib(n):
                            5
                                 elapsed seconds: 0.0
n:
     6
          fib(n):
                            8
                                 elapsed seconds: 0.0
n:
n:
     7
          fib(n):
                           13
                                 elapsed seconds: 0.0
     8
          fib(n):
                           21
                                 elapsed seconds: 0.0
n:
     9
                           34
                                 elapsed seconds: 0.0
          fib(n):
n:
                                 elapsed seconds: 0.0
    10
          fib(n):
                           55
n:
    11
          fib(n):
                           89
                                 elapsed seconds: 0.0
n:
    12
                                 elapsed seconds: 0.0
n:
          fib(n):
                          144
    13
          fib(n):
                          233
                                 elapsed seconds: 0.0009992122650146484
n:
          fib(n):
                                 elapsed seconds: 0.0
n:
    14
                          377
                                 elapsed seconds: 0.0
n:
    15
          fib(n):
                          610
    16
          fib(n):
                          987
                                 elapsed seconds: 0.0010001659393310547
n:
n:
    17
          fib(n):
                         1597
                                 elapsed seconds: 0.0010001659393310547
    18
          fib(n):
                         2584
                                 elapsed seconds: 0.0019998550415039062
n:
                                 elapsed seconds: 0.003000020980834961
                         4181
n:
    19
          fib(n):
    20
          fib(n):
                         6765
                                 elapsed seconds: 0.004999399185180664
n:
    21
          fib(n):
                        10946
                                 elapsed seconds: 0.007999897003173828
n:
    22
                                 elapsed seconds: 0.011999845504760742
n:
          fib(n):
                        17711
                                 elapsed seconds: 0.01999950408935547
    23
          fib(n):
                        28657
n:
    24
                                 elapsed seconds: 0.031000614166259766
n:
          fib(n):
                        46368
                                 elapsed seconds: 0.04999876022338867
    25
          fib(n):
                        75025
n:
    26
          fib(n):
                                 elapsed seconds: 0.08199858665466309
n:
                       121393
    27
          fib(n):
                       196418
                                 elapsed seconds: 0.1224210262298584
n:
    28
          fib(n):
                       317811
                                 elapsed seconds: 0.23323798179626465
n:
    29
          fib(n):
                       514229
                                 elapsed seconds: 0.3434438705444336
n:
          fib(n):
                                 elapsed seconds: 0.5441131591796875
n:
    30
                       832040
    31
          fib(n):
                      1346269
                                 elapsed seconds: 0.9086081981658936
n:
n:
    32
          fib(n):
                      2178309
                                 elapsed seconds: 1.4448347091674805
          fib(n):
    33
                                 elapsed seconds: 2.365004062652588
n:
                      3524578
    34
                                 elapsed seconds: 3.8220174312591553
n:
          fib(n):
                      5702887
    35
                     9227465
                                 elapsed seconds: 6.232163667678833
          fib(n):
n:
                                 elapsed seconds: 10.18271780014038
    36
          fib(n):
                     14930352
n:
    37
          fib(n):
                     24157817
                                 elapsed seconds: 16.28048849105835
n:
                     39088169
                                 elapsed seconds: 26.166386365890503
    38
          fib(n):
```

```
n: 39 fib(n): 63245986 elapsed seconds: 42.51878809928894
n: 40 fib(n): 102334155 elapsed seconds: 69.38479280471802
```

Aufgabe 5

```
fibonacci_caching.py
fibonacci_module.py
```

Da in der rekursiven Implementierung die kleineren Fibonacci Zahlen für jede Verästelung immer wieder neu berechnet werden müssen, hatte ich die Idee, alle bereits berechneten Fibonacci Zahlen in einem Cache zu speichern. Der Code für die neue Funktion fib_caching ist im Modul fibonacci_module.py:

```
def fib_caching(n, cache={}):
    """This implementation for calculating a Fibonacci number
    caches the already calculated numbers.
    """
    cached_fibonacci_number = cache.get(n, None)
    if cached_fibonacci_number is not None:
        return cached_fibonacci_number
    if n == 0 or n == 1:
        cache[n] = n
        return n
    fibonacci_number = fib_caching(n - 1, cache) + fib_caching(n - 2, cache)
    cache[n] = fibonacci_number
    return fibonacci_number
```

Ausprobiert mit fibonacci_caching.py zeigt sich, dass die Performance massiv besser ist, nicht einmal mehr im Sekundenbereich messbar:

```
Fibonacci numbers for range 0 to 100
     0
         fib(n):
                                      0
                                           elapsed seconds: 0.0
n:
     1
         fib(n):
                                      1
                                           elapsed seconds: 0.0
n:
     2
         fib(n):
                                      1
                                           elapsed seconds: 0.0
n:
n:
     3
         fib(n):
                                      2
                                           elapsed seconds: 0.0
                                      3
    4
         fib(n):
                                           elapsed seconds: 0.0
n:
   5
         fib(n):
                                      5
                                           elapsed seconds: 0.0
n:
                                      8
                                           elapsed seconds: 0.0
     6
         fib(n):
n:
   7
n:
         fib(n):
                                     13
                                           elapsed seconds: 0.0
    8
         fib(n):
                                     21
                                           elapsed seconds: 0.0
n:
   9
                                     34
                                           elapsed seconds: 0.0
n:
         fib(n):
n: 10
                                     55
                                           elapsed seconds: 0.0
         fib(n):
n: 11
                                     89
                                           elapsed seconds: 0.0
         fib(n):
n: 12
                                           elapsed seconds: 0.0
         fib(n):
                                    144
n: 13
         fib(n):
                                    233
                                           elapsed seconds: 0.0
n: 14
                                           elapsed seconds: 0.0
         fib(n):
                                    377
   15
         fib(n):
                                    610
                                           elapsed seconds: 0.0
n:
   16
         fib(n):
                                    987
                                           elapsed seconds: 0.0
n:
   17
          fib(n):
                                   1597
                                           elapsed seconds: 0.0
n:
```

n: 18 fib(n):					
n: 20 fib(n): 10946 clapsed seconds: 0.0 n: 21 fib(n): 10946 clapsed seconds: 0.0 n: 22 fib(n): 28657 clapsed seconds: 0.0 n: 23 fib(n): 28657 clapsed seconds: 0.0 n: 24 fib(n): 46368 clapsed seconds: 0.0 n: 25 fib(n): 75025 clapsed seconds: 0.0 n: 26 fib(n): 121393 clapsed seconds: 0.0 n: 27 fib(n): 196418 clapsed seconds: 0.0 n: 28 fib(n): 317811 clapsed seconds: 0.0 n: 29 fib(n): 317811 clapsed seconds: 0.0 n: 30 fib(n): 832040 clapsed seconds: 0.0 n: 31 fib(n): 1346269 clapsed seconds: 0.0 n: 32 fib(n): 2178309 clapsed seconds: 0.0 n: 33 fib(n): 3524578 clapsed seconds: 0.0 n: 34 fib(n): 5702887 clapsed seconds: 0.0 n: 35 fib(n): 9227465 clapsed seconds: 0.0 n: 36 fib(n): 14930352 clapsed seconds: 0.0 n: 37 fib(n): 24157817 clapsed seconds: 0.0 n: 38 fib(n): 3988169 clapsed seconds: 0.0 n: 39 fib(n): 63245986 clapsed seconds: 0.0 n: 41 fib(n): 102334155 clapsed seconds: 0.0 n: 44 fib(n): 12434159 clapsed seconds: 0.0 n: 44 fib(n): 12344159 clapsed seconds: 0.0 n: 45 fib(n): 14930437 clapsed seconds: 0.0 n: 44 fib(n): 1234159 clapsed seconds: 0.0 n: 45 fib(n): 24578429 clapsed seconds: 0.0 n: 46 fib(n): 12354159 clapsed seconds: 0.0 n: 47 fib(n): 24578429 clapsed seconds: 0.0 n: 48 fib(n): 24578429 clapsed seconds: 0.0 n: 49 fib(n): 139631193 clapsed seconds: 0.0 n: 50 fib(n): 139631209 clapsed seconds: 0.0 n: 51 fib(n): 236561207 clapsed seconds: 0.0 n: 52 fib(n): 3295128099 clapsed seconds: 0.0 n: 53 fib(n): 365435296162 clapsed seconds: 0.0 n: 54 fib(n): 139638862445 clapsed seconds: 0.0 n: 55 fib(n): 13963875920 clapsed seconds: 0.0 n: 61 fib(n): 15460875972 clapsed seconds: 0.0 n: 62 fib(n): 15460875972 clapsed seconds: 0.0 n: 63 fib(n): 15460875972 clapsed seconds: 0.0 n: 63 fib(n): 19932490799135 clapsed seconds: 0.0 n: 66 fib(n): 172723460248141 clapsed seconds: 0.0 n: 67 fib(n): 4965799537881 clapsed seconds: 0.0 n: 69 fib(n): 190392490799135 clapsed seconds: 0.0			• •		•
n: 21 fib(n): 19046 elapsed seconds: 0.0 n: 22 fib(n): 17711 elapsed seconds: 0.0 n: 23 fib(n): 28657 elapsed seconds: 0.0 n: 24 fib(n): 46368 elapsed seconds: 0.0 n: 25 fib(n): 75025 elapsed seconds: 0.0 n: 26 fib(n): 121393 elapsed seconds: 0.0 n: 27 fib(n): 196418 elapsed seconds: 0.0 n: 28 fib(n): 317811 elapsed seconds: 0.0 n: 29 fib(n): 317811 elapsed seconds: 0.0 n: 30 fib(n): 832040 elapsed seconds: 0.0 n: 31 fib(n): 1346269 elapsed seconds: 0.0 n: 33 fib(n): 3524578 elapsed seconds: 0.0 n: 34 fib(n): 5702887 elapsed seconds: 0.0 n: 35 fib(n): 9227465 elapsed seconds: 0.0 n: 36 fib(n): 1493052 elapsed seconds: 0.0 n: 37 fib(n): 24157817 elapsed seconds: 0.0 n: 38 fib(n): 3988169 elapsed seconds: 0.0 n: 39 fib(n): 6324598 elapsed seconds: 0.0 n: 40 fib(n): 102334155 elapsed seconds: 0.0 n: 41 fib(n): 165580141 elapsed seconds: 0.0 n: 44 fib(n): 7674296 elapsed seconds: 0.0 n: 44 fib(n): 13499372 elapsed seconds: 0.0 n: 45 fib(n): 13499372 elapsed seconds: 0.0 n: 46 fib(n): 13499373 elapsed seconds: 0.0 n: 47 fib(n): 26794296 elapsed seconds: 0.0 n: 48 fib(n): 3988169 elapsed seconds: 0.0 n: 49 fib(n): 31499373 elapsed seconds: 0.0 n: 49 fib(n): 32545986 elapsed seconds: 0.0 n: 40 fib(n): 32542986 elapsed seconds: 0.0 n: 45 fib(n): 32542986 elapsed seconds: 0.0 n: 46 fib(n): 32542986 elapsed seconds: 0.0 n: 47 fib(n): 32542986 elapsed seconds: 0.0 n: 48 fib(n): 32542986 elapsed seconds: 0.0 n: 49 fib(n): 32542986 elapsed seconds: 0.0 n: 51 fib(n): 32542986 elapsed seconds: 0.0 n: 52 fib(n): 32542986 elapsed seconds: 0.0 n: 54 fib(n): 32542986 elapsed seconds: 0.0 n: 55 fib(n): 32552960 elapsed seconds: 0.0 n: 56 fib(n): 3255383377 elapsed seconds: 0.0 n: 57 fib(n): 32552960 elapsed seconds: 0.0 n: 58 fib(n): 325843978999 elapsed seconds: 0.0 n: 59 fib(n): 3258439789999 elapsed seconds: 0.0 n: 62 fib(n): 48572975881 elapsed seconds: 0.0 n: 63 fib(n): 32584398732 elapsed seconds: 0.0	n:				•
n: 22 fib(n): 17711 elapsed seconds: 0.0 n: 23 fib(n): 28657 elapsed seconds: 0.0 n: 24 fib(n): 46368 elapsed seconds: 0.0 n: 25 fib(n): 75025 elapsed seconds: 0.0 n: 26 fib(n): 121393 elapsed seconds: 0.0 n: 27 fib(n): 196418 elapsed seconds: 0.0 n: 28 fib(n): 317811 elapsed seconds: 0.0 n: 29 fib(n): 514229 elapsed seconds: 0.0 n: 30 fib(n): 832040 elapsed seconds: 0.0 n: 31 fib(n): 1346620 elapsed seconds: 0.0 n: 32 fib(n): 2178309 elapsed seconds: 0.0 n: 33 fib(n): 3524578 elapsed seconds: 0.0 n: 34 fib(n): 5702887 elapsed seconds: 0.0 n: 35 fib(n): 9227465 elapsed seconds: 0.0 n: 36 fib(n): 24157817 elapsed seconds: 0.0 n: 37 fib(n): 24157817 elapsed seconds: 0.0 n: 38 fib(n): 39088169 elapsed seconds: 0.0 n: 39 fib(n): 6324598 elapsed seconds: 0.0 n: 39 fib(n): 6324598 elapsed seconds: 0.0 n: 41 fib(n): 16384914 elapsed seconds: 0.0 n: 42 fib(n): 1234155 elapsed seconds: 0.0 n: 44 fib(n): 1633493437 elapsed seconds: 0.0 n: 44 fib(n): 18331193 elapsed seconds: 0.0 n: 44 fib(n): 18331193 elapsed seconds: 0.0 n: 45 fib(n): 24157817 elapsed seconds: 0.0 n: 46 fib(n): 134993179 elapsed seconds: 0.0 n: 47 fib(n): 257914296 elapsed seconds: 0.0 n: 48 fib(n): 39088169 elapsed seconds: 0.0 n: 49 fib(n): 771840873 elapsed seconds: 0.0 n: 45 fib(n): 134993179 elapsed seconds: 0.0 n: 46 fib(n): 134993179 elapsed seconds: 0.0 n: 47 fib(n): 2971215073 elapsed seconds: 0.0 n: 48 fib(n): 3936591174 elapsed seconds: 0.0 n: 51 fib(n): 236591174 elapsed seconds: 0.0 n: 52 fib(n): 32951280099 elapsed seconds: 0.0 n: 53 fib(n): 3533691173 elapsed seconds: 0.0 n: 54 fib(n): 3533691173 elapsed seconds: 0.0 n: 55 fib(n): 3533691772 elapsed seconds: 0.0 n: 56 fib(n): 3533691772 elapsed seconds: 0.0 n: 57 fib(n): 365435296162 elapsed seconds: 0.0 n: 61 fib(n): 365435296162 elapsed seconds: 0.0 n: 62 fib(n): 353669187729 elapsed seconds: 0.0 n: 63 fib(n): 365435296182 elapsed seconds: 0.0 n: 64 fib(n): 365435296183 elapsed seconds: 0.0 n: 65 fib(n): 372723460248141 elapsed seconds: 0.0 n: 66 fib(n): 3727346048141 elapsed seconds: 0	n:	20	fib(n):	6765	elapsed seconds: 0.0
n: 23 fib(n): 46368 elapsed seconds: 0.0 n: 24 fib(n): 46368 elapsed seconds: 0.0 n: 25 fib(n): 75025 elapsed seconds: 0.0 n: 26 fib(n): 121393 elapsed seconds: 0.0 n: 27 fib(n): 196418 elapsed seconds: 0.0 n: 28 fib(n): 317811 elapsed seconds: 0.0 n: 29 fib(n): 514229 elapsed seconds: 0.0 n: 30 fib(n): 832040 elapsed seconds: 0.0 n: 31 fib(n): 1346269 elapsed seconds: 0.0 n: 32 fib(n): 2178309 elapsed seconds: 0.0 n: 33 fib(n): 3524578 elapsed seconds: 0.0 n: 34 fib(n): 9227465 elapsed seconds: 0.0 n: 35 fib(n): 9227465 elapsed seconds: 0.0 n: 36 fib(n): 14930352 elapsed seconds: 0.0 n: 37 fib(n): 24157817 elapsed seconds: 0.0 n: 39 fib(n): 6324598 elapsed seconds: 0.0 n: 39 fib(n): 6324598 elapsed seconds: 0.0 n: 39 fib(n): 6324598 elapsed seconds: 0.0 n: 40 fib(n): 102334155 elapsed seconds: 0.0 n: 41 fib(n): 165580141 elapsed seconds: 0.0 n: 42 fib(n): 761408733 elapsed seconds: 0.0 n: 43 fib(n): 13490370 elapsed seconds: 0.0 n: 44 fib(n): 1237496 elapsed seconds: 0.0 n: 45 fib(n): 1336311903 elapsed seconds: 0.0 n: 46 fib(n): 1336311903 elapsed seconds: 0.0 n: 47 fib(n): 2971215073 elapsed seconds: 0.0 n: 48 fib(n): 3136311903 elapsed seconds: 0.0 n: 49 fib(n): 771872099 elapsed seconds: 0.0 n: 50 fib(n): 3295808099 elapsed seconds: 0.0 n: 51 fib(n): 2936511074 elapsed seconds: 0.0 n: 52 fib(n): 3295808099 elapsed seconds: 0.0 n: 53 fib(n): 3295808099 elapsed seconds: 0.0 n: 54 fib(n): 3295808099 elapsed seconds: 0.0 n: 55 fib(n): 3295808099 elapsed seconds: 0.0 n: 56 fib(n): 32958308099 elapsed seconds: 0.0 n: 57 fib(n): 365435296162 elapsed seconds: 0.0 n: 59 fib(n): 32958308099 elapsed seconds: 0.0 n: 59 fib(n): 32958308099 elapsed seconds: 0.0 n: 60 fib(n): 3498579012883 elapsed seconds: 0.0 n: 61 fib(n): 366435296162 elapsed seconds: 0.0 n: 62 fib(n): 4952739537881 elapsed seconds: 0.0 n: 63 fib(n): 36643608094 elapsed seconds: 0.0 n: 64 fib(n): 1716768017565 elapsed seconds: 0.0 n: 65 fib(n): 1716768017565 elapsed seconds: 0.0 n: 66 fib(n): 1716768017565 elapsed seconds: 0.0 n: 69 fib(n): 19093249070	n:	21	fib(n):	10946	elapsed seconds: 0.0
n: 24 fib(n): 46368 elapsed seconds: 0.0 n: 25 fib(n): 75025 elapsed seconds: 0.0 n: 26 fib(n): 121393 elapsed seconds: 0.0 n: 27 fib(n): 196418 elapsed seconds: 0.0 n: 28 fib(n): 317811 elapsed seconds: 0.0 n: 29 fib(n): 514229 elapsed seconds: 0.0 n: 30 fib(n): 832040 elapsed seconds: 0.0 n: 31 fib(n): 1346269 elapsed seconds: 0.0 n: 32 fib(n): 2178309 elapsed seconds: 0.0 n: 33 fib(n): 3524578 elapsed seconds: 0.0 n: 34 fib(n): 9227465 elapsed seconds: 0.0 n: 35 fib(n): 9227465 elapsed seconds: 0.0 n: 36 fib(n): 14930352 elapsed seconds: 0.0 n: 37 fib(n): 24157817 elapsed seconds: 0.0 n: 38 fib(n): 3988169 elapsed seconds: 0.0 n: 39 fib(n): 6324598 elapsed seconds: 0.0 n: 40 fib(n): 102334155 elapsed seconds: 0.0 n: 41 fib(n): 16258041 elapsed seconds: 0.0 n: 42 fib(n): 267914296 elapsed seconds: 0.0 n: 43 fib(n): 34349437 elapsed seconds: 0.0 n: 44 fib(n): 134903170 elapsed seconds: 0.0 n: 45 fib(n): 134903170 elapsed seconds: 0.0 n: 46 fib(n): 134903170 elapsed seconds: 0.0 n: 47 fib(n): 2971215073 elapsed seconds: 0.0 n: 48 fib(n): 134903170 elapsed seconds: 0.0 n: 49 fib(n): 13586269025 elapsed seconds: 0.0 n: 50 fib(n): 12586269025 elapsed seconds: 0.0 n: 51 fib(n): 32951280099 elapsed seconds: 0.0 n: 52 fib(n): 32951280099 elapsed seconds: 0.0 n: 53 fib(n): 32951280099 elapsed seconds: 0.0 n: 54 fib(n): 32951280099 n: 55 fib(n): 1348083759910 elapsed seconds: 0.0 n: 57 fib(n): 32951280099 elapsed seconds: 0.0 n: 59 fib(n): 956722026041 elapsed seconds: 0.0 n: 66 fib(n): 2574739781961 elapsed seconds: 0.0 n: 67 fib(n): 498573957881 elapsed seconds: 0.0 n: 68 fib(n): 177680877729 elapsed seconds: 0.0 n: 69 fib(n): 1716680177565 elapsed seconds: 0.0 n: 68 fib(n): 1716680177565 elapsed seconds: 0.0 n: 69 fib(n): 1716680177565 elapsed seconds: 0.0 n: 69 fib(n): 171669034060994 elapsed seconds: 0.0 n: 69 fib(n): 171669034060994 elapsed seconds: 0.0 n: 60 fib(n): 171669034060994 elapsed seconds: 0.0 n: 60 fib(n): 171669034060994 elapsed seconds: 0.0	n:	22	fib(n):	17711	elapsed seconds: 0.0
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n:	98	` '	135301852344706746049	elapsed seconds: 0	
n:	99	fib(n):	218922995834555169026	elapsed seconds: 0	0.0
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