Institute of Mathematics and Image Computing, Lübeck

MA4030: Optimierung, Sommersemester 2025

Übungsblatt 4

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A4\code\A4.py

```python
import numpy as np
import matplotlib
import matplotlib.pyplot as plt
from utils import *


def petras_optimizer(f, x0=0, d0=1, kmax=50, plot=False):
    """
    Petras 1D-Optimierungsverfahren

    Input:
        f: Funktion,
        x0: float (Startwert),
        d0: float (Initialer Abstand),
        kmax: Skalar (Maximale Anzahl an Iterationen),
        plot: Parameter zur Steuerung eines Live-Plots im Iterationsverlauf:
                False => kein Plot
                [xmin, xmax] => Erstellung eines Plot auf Intervall (xmin, xmax)

    Output:
        log: Dictionary vom Verlauf der Optimierung.
    """
    # Dictionary zum Abspeichern der Ergebnisse.
    log = {
        'x0': x0,                 # Startwert
        'd0': d0,                 # Initialer Abstand
        'xpetra': None,           # Erreichter Minimierer
        'x_list': [],             # Liste der Iterierten (xk)
        'val_list': [],           # Liste von Funktionswerten der Iterierten (f(xk))
    }

    print(f'### Starte Petras Optimierung fÃ¼r x0={x0}, d0={d0} ###')
    # Initialisiere Verfahren
    xk = x0
    dk = d0

    # Plot initialisieren
    if plot is not False:
        matplotlib.use('TkAgg')  # or 'Qt5Agg' depending on your system
        plt.ion()
        x = np.linspace(plot[0], plot[1], 200)
        y = f(x)
        _, ax = plt.subplots()
        ax.plot(x, y, label='f(x)')
        # Initialisiere Punkte fÃ¼r Plot. Koordinaten kÃ¶nnen mittels plot_xo.set_data([x], [y]) aktualisi
```

```
    plot_xo, = ax.plot([], [], 'ko', label=r'$x_\circ$')  # Plot-Punkt der aktuellen Iterierten x_\circ
    plot_xm, = ax.plot([], [], 'ro', label=r'$x_-$')  # Plot-Punkt des aktuellen x_-
    plot_xp, = ax.plot([], [], 'ro', label=r'$x_+$')  # Plot-Punkt des aktuellen x_+
    plt.legend()

# TODO: Aufgabenteil b / c. Verfahren implementieren / Live-Visualisierung implementieren
# BEGIN SOLUTION
for k in range(kmax):
    # Zuweisungen
    xm=xk-dk
    xp=xk+dk
    y0=f(xk)
    ym=f(xm)
    yp=f(xp)
    # Ausgabe
    print(f"Iteration {k}:")
    print(f"  x- = {xm}, f(x-) = {ym}")
    print(f"  x0 = {xk}, f(xÃ°) = {y0:}")
    print(f"  x+ = {xp}, f(x+) = {yp:}")

    # Loggen der Werte
    log["x_list"].append(xk)
    log["val_list"].append(y0)

    # Fallunterscheidungen
    if ym<y0 and yp<y0:
        dk = 0.5 * dk
        if ym<yp:
            xk=xm
        else:
            xk=xp
    elif ym<y0 and yp>=y0:
        xk=xm
        dk=2*dk
    elif ym>=y0 and yp<y0:
        xk=xp
        dk=2*dk
    elif ym>=y0 and yp>=y0:
        xk=xk
        dk=0.5*dk
    # Aufgabenteil c)
    if k<20:
        plot_xm.set_data([xm], [ym])
        plot_xo.set_data([xk], [y0])
        plot_xp.set_data([xp], [yp])
        plt.draw()
        plt.pause(0.25)


# END SOLUTION

log['xpetra'] = xk
print(f'### Minimaler Wert f(x)={f(xk): .4f} gefunden in xk={xk: .8f} ###\n')

if plot is not False:
    plt.ioff()
```

```
        plt.show()

    return log


if __name__ == '__main__':
    # Teste Optimierungsverfahren fÃ¼r f(x) = x**2
    f = lambda x: x**2
    log = petras_optimizer(f, x0=2, d0=1, plot=[-2,4])
    fig = plot_iteration_process(log, r'Iterationsverlauf fÃ¼r $f(x)=x^2$ mit x0=2, d0=1')
    plt.show()

    # Hinweis: Die plot-Funktion aus utils.py soll fÃ¼r publish.py nur die Plots erstellen und die Figure
    # Stellen Sie die Abbildung bitte dar, indem Sie HIER plt.show() aufrufen.

    # TODO: Aufgabenteil d. Verfahren fÃ¼r andere Startwerte testen
    # BEGIN SOLUTION
    f1_x = petras_optimizer(f, x0=2, d0=0.1, plot=[-4,4])
    figure1 = plot_iteration_process(f1_x, r'Iterationsverlauf fÃ¼r $f(x)=x^2$ mit x0=2, d0=0.1')
    plt.show()
    f2_x = petras_optimizer(f, x0=-10, d0=1, plot=[-15,15])
    figure2 = plot_iteration_process(f2_x, r'Iterationsverlauf fÃ¼r $f(x)=x^2$ mit x0=-10, d0=1')
    plt.show()

    print("Diskussion der Ergebnisse: \n"
          "Im ersten Durchlauf aus d) wird die Schrittweite im Vergleich zu vorher verringert. \n"
          "Der Startwert bleibt der gleiche. Das Verfahren benÃ¶tigt mehr Iterationen um auf den Minimiere
          "Im zweiten Durchlauf ist die Schrittweite wieder 1, der Startwert jedoch weiter weg vom Minimie
          "Auch hier braucht es mehr Iterationen um auf den Minimierer zu kommen.\n"
          "Das wÃ¤hlen eines sinnvollen Startwertes und einer geeigneten Schrittweite beschleunigen das Ve
    )
    # END SOLUTION

    # TODO: Aufgabenteil e. Verfahren fÃ¼r f(x) = x**4 - 4 * x**2 testen
    # BEGIN SOLUTION
    f2 = lambda x: x**4 - 4*x**2
    f3_x = petras_optimizer(f2, x0=0, d0=1, plot=[-5,5])
    figure3 = plot_iteration_process(f3_x, r'Iterationsverlauf fÃ¼r $f(x)=x^4-4x^2$ mit x0=0, d0=1')
    plt.show()
    # END SOLUTION

    # TODO: Aufgabenteil f. Verfahren fÃ¼r f(x) = x und f(x) = cos(pi * x) + 1 / (1 + x**2) testen
    # BEGIN SOLUTION
    f3 = lambda x: x
    f4_x = petras_optimizer(f3, x0=0, d0=1, plot=[-10**6, 5])
    figure4 = plot_iteration_process(f4_x, r'Iterationsverlauf fÃ¼r $f(x)=x$ mit x0=0, d0=1')
    plt.show()

    f4 = lambda x: np.cos(np.pi * x) + 1 / (1 + x ** 2)
    f5_x = petras_optimizer(f4, x0=1, d0=2, plot=[-5, 2.5*10**6])
    figure5 = plot_iteration_process(f5_x, r'Iterationsverlauf fÃ¼r $f(x) = cos(\pi x) + \frac{1}{1 + x^2}
    plt.show()

    print(
        "Diskussion der Ergebnisse:\n"
        "Bei $f(x) = x$ lÃ¤sst sich kein Minimierer finden, weshalb die Schrittweite sich immer verdoppelt
```

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        "Offensiochtlich kann kein Minimierer gefunden werden, was sich aber nicht durch ausschlieÃŸliches
        "Bei $f(x) = cos(pi * x) + 1 / (1 + x**2)$ hat bei zwei lokalen Minima das mit BetragsmÃ¤ÃŸig grÃ¶
        "auch einen niedrigeren Funktionswert. Daher findet sich immerwieder ein besserer Wert je weiter d
        "Auch hier mit immer grÃ¶ÃŸeren Schrittweiten, bis dann die Maschinengenauigkeit erreicht ist. Dan
        "Der innerhalb der Maschinenzahlen beste Minimierer wurde gefunden."
        "Der wesentliche Unterschied zwischen den beiden Beispielen ist, dass das die Minima bei der zweit
        "wÃ¤hrend bei der ersten Funktion dies nicht der Fall ist.\n"
        "Somit kann zumindest bei der zweiten Funktion der Algorithmus einen nicht ganz 'unsinnigen' Wert
    )
    # END SOLUTION
#TERMINAL OUTPUT:
```

Starte Petras Optimierung für x0=2, d0=1

Iteration 0:

x- = 1, f(x-) = 1

x0 = 2, f(x°) = 4

x+ = 3, f(x+) = 9

Iteration 1:

x- = -1, f(x-) = 1

x0 = 1, f(x°) = 1

x+ = 3, f(x+) = 9

Iteration 2:

x- = 0.0, f(x-) = 0.0

x0 = 1, f(x°) = 1

x+ = 2.0, f(x+) = 4.0

Iteration 3:

x- = -2.0, f(x-) = 4.0

x0 = 0.0, f(x°) = 0.0

x+ = 2.0, f(x+) = 4.0

Iteration 4:

x- = -1.0, f(x-) = 1.0

x0 = 0.0, f(x°) = 0.0

x+ = 1.0, f(x+) = 1.0

Iteration 5:

x- = -0.5, f(x-) = 0.25

x0 = 0.0, f(x°) = 0.0

x+ = 0.5, f(x+) = 0.25

Iteration 6:

x- = -0.25, f(x-) = 0.0625

x0 = 0.0, f(x°) = 0.0

x+ = 0.25, f(x+) = 0.0625

Iteration 7:

x- = -0.125, f(x-) = 0.015625

x0 = 0.0, f(x°) = 0.0

x+ = 0.125, f(x+) = 0.015625

Iteration 8:

x- = -0.0625, f(x-) = 0.00390625

x0 = 0.0, f(x°) = 0.0

x+ = 0.0625, f(x+) = 0.00390625

Iteration 9:

x- = -0.03125, f(x-) = 0.0009765625

x0 = 0.0, f(x°) = 0.0

x+ = 0.03125, f(x+) = 0.0009765625

Iteration 10:

x- = -0.015625, f(x-) = 0.000244140625

x0 = 0.0, f(x°) = 0.0

x+ = 0.015625, f(x+) = 0.000244140625

Iteration 11:

x- = -0.0078125, f(x-) = 6.103515625e-05

x0 = 0.0, f(x°) = 0.0

x+ = 0.0078125, f(x+) = 6.103515625e-05

Iteration 12:

x- = -0.00390625, f(x-) = 1.52587890625e-05

x0 = 0.0, f(x°) = 0.0

x+ = 0.00390625, f(x+) = 1.52587890625e-05

Iteration 13:

x- = -0.001953125, f(x-) = 3.814697265625e-06

x0 = 0.0, f(x°) = 0.0

x+ = 0.001953125, f(x+) = 3.814697265625e-06

Iteration 14:

x- = -0.0009765625, f(x-) = 9.5367431640625e-07

x0 = 0.0, f(x°) = 0.0

x+ = 0.0009765625, f(x+) = 9.5367431640625e-07

Iteration 15:

x- = -0.00048828125, f(x-) = 2.384185791015625e-07

x0 = 0.0, f(x°) = 0.0

x+ = 0.00048828125, f(x+) = 2.384185791015625e-07

Iteration 16:

x- = -0.000244140625, f(x-) = 5.960464477539063e-08

x0 = 0.0, f(x°) = 0.0

x+ = 0.000244140625, f(x+) = 5.960464477539063e-08

Iteration 17:

x- = -0.0001220703125, f(x-) = 1.4901161193847656e-08

x0 = 0.0, f(x°) = 0.0

x+ = 0.0001220703125, f(x+) = 1.4901161193847656e-08

Iteration 18:

x- = -6.103515625e-05, f(x-) = 3.725290298461914e-09

x0 = 0.0, f(x°) = 0.0

x+ = 6.103515625e-05, f(x+) = 3.725290298461914e-09

Iteration 19:

x- = -3.0517578125e-05, f(x-) = 9.313225746154785e-10

x0 = 0.0, f(x°) = 0.0

x+ = 3.0517578125e-05, f(x+) = 9.313225746154785e-10

Iteration 20:

x- = -1.52587890625e-05, f(x-) = 2.3283064365386963e-10

x0 = 0.0, f(x°) = 0.0

x+ = 1.52587890625e-05, f(x+) = 2.3283064365386963e-10

Iteration 21:

x- = -7.62939453125e-06, f(x-) = 5.820766091346741e-11

x0 = 0.0, f(x°) = 0.0

x+ = 7.62939453125e-06, f(x+) = 5.820766091346741e-11

Iteration 22:

x- = -3.814697265625e-06, f(x-) = 1.4551915228366852e-11

x0 = 0.0, f(x°) = 0.0

x+ = 3.814697265625e-06, f(x+) = 1.4551915228366852e-11

Iteration 23:

x- = -1.9073486328125e-06, f(x-) = 3.637978807091713e-12

x0 = 0.0, f(x°) = 0.0

x+ = 1.9073486328125e-06, f(x+) = 3.637978807091713e-12

Iteration 24:

x- = -9.5367431640625e-07, f(x-) = 9.094947017729282e-13

x0 = 0.0, f(x°) = 0.0

x+ = 9.5367431640625e-07, f(x+) = 9.094947017729282e-13

Iteration 25:

x- = -4.76837158203125e-07, f(x-) = 2.2737367544323206e-13

x0 = 0.0, f(x°) = 0.0

x+ = 4.76837158203125e-07, f(x+) = 2.2737367544323206e-13

Iteration 26:

x- = -2.384185791015625e-07, f(x-) = 5.684341886080802e-14

x0 = 0.0, f(x°) = 0.0

x+ = 2.384185791015625e-07, f(x+) = 5.684341886080802e-14

Iteration 27:

x- = -1.1920928955078125e-07, f(x-) = 1.4210854715202004e-14

x0 = 0.0, f(x°) = 0.0

x+ = 1.1920928955078125e-07, f(x+) = 1.4210854715202004e-14

Iteration 28:

x- = -5.960464477539063e-08, f(x-) = 3.552713678800501e-15

x0 = 0.0, f(x°) = 0.0

x+ = 5.960464477539063e-08, f(x+) = 3.552713678800501e-15

Iteration 29:

x- = -2.9802322387695312e-08, f(x-) = 8.881784197001252e-16

x0 = 0.0, f(x°) = 0.0

x+ = 2.9802322387695312e-08, f(x+) = 8.881784197001252e-16

Iteration 30:

x- = -1.4901161193847656e-08, f(x-) = 2.220446049250313e-16

x0 = 0.0, f(x°) = 0.0

x+ = 1.4901161193847656e-08, f(x+) = 2.220446049250313e-16

Iteration 31:

x- = -7.450580596923828e-09, f(x-) = 5.551115123125783e-17

x0 = 0.0, f(x°) = 0.0

x+ = 7.450580596923828e-09, f(x+) = 5.551115123125783e-17

Iteration 32:

x- = -3.725290298461914e-09, f(x-) = 1.3877787807814457e-17

x0 = 0.0, f(x°) = 0.0

x+ = 3.725290298461914e-09, f(x+) = 1.3877787807814457e-17

Iteration 33:

x- = -1.862645149230957e-09, f(x-) = 3.469446951953614e-18

x0 = 0.0, f(x°) = 0.0

x+ = 1.862645149230957e-09, f(x+) = 3.469446951953614e-18

Iteration 34:

x- = -9.313225746154785e-10, f(x-) = 8.673617379884035e-19

x0 = 0.0, f(x°) = 0.0

x+ = 9.313225746154785e-10, f(x+) = 8.673617379884035e-19

Iteration 35:

x- = -4.656612873077393e-10, f(x-) = 2.168404344971009e-19

x0 = 0.0, f(x°) = 0.0

x+ = 4.656612873077393e-10, f(x+) = 2.168404344971009e-19

Iteration 36:

x- = -2.3283064365386963e-10, f(x-) = 5.421010862427522e-20

x0 = 0.0, f(x°) = 0.0

x+ = 2.3283064365386963e-10, f(x+) = 5.421010862427522e-20

Iteration 37:

x- = -1.1641532182693481e-10, f(x-) = 1.3552527156068805e-20

x0 = 0.0, f(x°) = 0.0

x+ = 1.1641532182693481e-10, f(x+) = 1.3552527156068805e-20

Iteration 38:

x- = -5.820766091346741e-11, f(x-) = 3.3881317890172014e-21

x0 = 0.0, f(x°) = 0.0

x+ = 5.820766091346741e-11, f(x+) = 3.3881317890172014e-21

Iteration 39:

x- = -2.9103830456733704e-11, f(x-) = 8.470329472543003e-22

x0 = 0.0, f(x°) = 0.0

x+ = 2.9103830456733704e-11, f(x+) = 8.470329472543003e-22

Iteration 40:

x- = -1.4551915228366852e-11, f(x-) = 2.117582368135751e-22

x0 = 0.0, f(x°) = 0.0

x+ = 1.4551915228366852e-11, f(x+) = 2.117582368135751e-22

Iteration 41:

x- = -7.275957614183426e-12, f(x-) = 5.293955920339377e-23

x0 = 0.0, f(x°) = 0.0

x+ = 7.275957614183426e-12, f(x+) = 5.293955920339377e-23

Iteration 42:

x- = -3.637978807091713e-12, f(x-) = 1.3234889800848443e-23

x0 = 0.0, f(x°) = 0.0

x+ = 3.637978807091713e-12, f(x+) = 1.3234889800848443e-23

Iteration 43:

x- = -1.8189894035458565e-12, f(x-) = 3.308722450212111e-24

x0 = 0.0, f(x°) = 0.0

x+ = 1.8189894035458565e-12, f(x+) = 3.308722450212111e-24

Iteration 44:

x- = -9.094947017729282e-13, f(x-) = 8.271806125530277e-25

x0 = 0.0, f(x°) = 0.0

x+ = 9.094947017729282e-13, f(x+) = 8.271806125530277e-25

Iteration 45:

x- = -4.547473508864641e-13, f(x-) = 2.0679515313825692e-25

x0 = 0.0, f(x°) = 0.0

x+ = 4.547473508864641e-13, f(x+) = 2.0679515313825692e-25

Iteration 46:

x- = -2.2737367544323206e-13, f(x-) = 5.169878828456423e-26

x0 = 0.0, f(x°) = 0.0

x+ = 2.2737367544323206e-13, f(x+) = 5.169878828456423e-26

Iteration 47:

x- = -1.1368683772161603e-13, f(x-) = 1.2924697071141057e-26

x0 = 0.0, f(x°) = 0.0

x+ = 1.1368683772161603e-13, f(x+) = 1.2924697071141057e-26

Iteration 48:

x- = -5.684341886080802e-14, f(x-) = 3.231174267785264e-27

x0 = 0.0, f(x°) = 0.0

x+ = 5.684341886080802e-14, f(x+) = 3.231174267785264e-27

Iteration 49:

x- = -2.842170943040401e-14, f(x-) = 8.077935669463161e-28

x0 = 0.0, f(x°) = 0.0

x+ = 2.842170943040401e-14, f(x+) = 8.077935669463161e-28

Minimaler Wert f(x)= 0.0000 gefunden in xk= 0.00000000

Starte Petras Optimierung für x0=2, d0=0.1

Iteration 0:

x- = 1.9, f(x-) = 3.61

x0 = 2, f(x°) = 4

x+ = 2.1, f(x+) = 4.41

Iteration 1:

x- = 1.7, f(x-) = 2.8899999999999997

x0 = 1.9, f(x°) = 3.61

x+ = 2.1, f(x+) = 4.41

Iteration 2:

x- = 1.2999999999999998, f(x-) = 1.6899999999999995

x0 = 1.7, f(x°) = 2.8899999999999997

x+ = 2.1, f(x+) = 4.41

Iteration 3:

x- = 0.4999999999999998, f(x-) = 0.24999999999999978

x0 = 1.2999999999999998, f(x°) = 1.6899999999999995

x+ = 2.0999999999999996, f(x+) = 4.409999999999998

Iteration 4:

x- = -1.1000000000000003, f(x-) = 1.2100000000000006

x0 = 0.4999999999999998, f(x°) = 0.24999999999999978

x+ = 2.0999999999999996, f(x+) = 4.409999999999998

Iteration 5:

x- = -0.30000000000000027, f(x-) = 0.09000000000000016

x0 = 0.4999999999999998, f(x°) = 0.24999999999999978

x+ = 1.2999999999999998, f(x+) = 1.6899999999999995

Iteration 6:

x- = -1.9000000000000004, f(x-) = 3.610000000000001

x0 = -0.30000000000000027, f(x°) = 0.09000000000000016

x+ = 1.2999999999999998, f(x+) = 1.6899999999999995

Iteration 7:

x- = -1.1000000000000003, f(x-) = 1.2100000000000006

x0 = -0.30000000000000027, f(x°) = 0.09000000000000016

x+ = 0.4999999999999998, f(x+) = 0.24999999999999978

Iteration 8:

x- = -0.7000000000000003, f(x-) = 0.4900000000000004

x0 = -0.30000000000000027, f(x°) = 0.09000000000000016

x+ = 0.09999999999999976, f(x+) = 0.009999999999999952

Iteration 9:

x- = -0.7000000000000003, f(x-) = 0.4900000000000004

x0 = 0.09999999999999976, f(x°) = 0.009999999999999952

x+ = 0.8999999999999998, f(x+) = 0.8099999999999996

Iteration 10:

x- = -0.30000000000000027, f(x-) = 0.09000000000000016

x0 = 0.09999999999999976, f(x°) = 0.009999999999999952

x+ = 0.4999999999999998, f(x+) = 0.24999999999999978

Iteration 11:

x- = -0.10000000000000026, f(x-) = 0.01000000000000005

x0 = 0.09999999999999976, f(x°) = 0.009999999999999952

x+ = 0.29999999999999977, f(x+) = 0.08999999999999986

Iteration 12:

x- = -2.498001805406602e-16, f(x-) = 6.240013019814644e-32

x0 = 0.09999999999999976, f(x°) = 0.009999999999999952

x+ = 0.19999999999999976, f(x+) = 0.039999999999999904

Iteration 13:

x- = -0.20000000000000026, f(x-) = 0.040000000000000105

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 0.19999999999999976, f(x+) = 0.039999999999999904

Iteration 14:

x- = -0.10000000000000026, f(x-) = 0.01000000000000005

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 0.09999999999999976, f(x+) = 0.009999999999999952

Iteration 15:

x- = -0.05000000000000025, f(x-) = 0.002500000000000025

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 0.04999999999999975, f(x+) = 0.0024999999999999753

Iteration 16:

x- = -0.02500000000000025, f(x-) = 0.0006250000000000126

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 0.02499999999999975, f(x+) = 0.0006249999999999875

Iteration 17:

x- = -0.01250000000000025, f(x-) = 0.00015625000000000626

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 0.012499999999999751, f(x+) = 0.00015624999999999377

Iteration 18:

x- = -0.00625000000000025, f(x-) = 3.9062500000003125e-05

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 0.006249999999997505, f(x+) = 3.9062499999996884e-05

Iteration 19:

x- = -0.00312500000000025, f(x-) = 9.765625000001562e-06

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 0.003124999999997504, f(x+) = 9.76562499999844e-06

Iteration 20:

x- = -0.001562500000002499, f(x-) = 2.441406250000781e-06

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 0.001562499999997503, f(x+) = 2.4414062499992195e-06

Iteration 21:

x- = -0.000781250000002498, f(x-) = 6.103515625003904e-07

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 0.000781249999997502, f(x+) = 6.103515624996097e-07

Iteration 22:

x- = -0.000390625000002498, f(x-) = 1.5258789062519516e-07

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 0.0003906249999997502, f(x+) = 1.5258789062480487e-07

Iteration 23:

x- = -0.0001953125000002498, f(x-) = 3.814697265634758e-08

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 0.0001953124999997502, f(x+) = 3.8146972656152427e-08

Iteration 24:

x- = -9.76562500002498e-05, f(x-) = 9.53674316411129e-09

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 9.76562499997502e-05, f(x+) = 9.536743164013711e-09

Iteration 25:

x- = -4.88281250002498e-05, f(x-) = 2.38418579104002e-09

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 4.88281249997502e-05, f(x+) = 2.3841857909912307e-09

Iteration 26:

x- = -2.44140625002498e-05, f(x-) = 5.960464477661036e-10

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 2.44140624997502e-05, f(x+) = 5.960464477417091e-10

Iteration 27:

x- = -1.2207031250249801e-05, f(x-) = 1.4901161194457521e-10

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 1.22070312497502e-05, f(x+) = 1.4901161193237794e-10

Iteration 28:

x- = -6.1035156252498005e-06, f(x-) = 3.7252902987668465e-11

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 6.1035156247502e-06, f(x+) = 3.7252902981569824e-11

Iteration 29:

x- = -3.0517578127498003e-06, f(x-) = 9.313225747679446e-12

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 3.0517578122502e-06, f(x+) = 9.313225744630127e-12

Iteration 30:

x- = -1.5258789064998003e-06, f(x-) = 2.328306437301026e-12

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 1.5258789060002e-06, f(x+) = 2.328306435776367e-12

Iteration 31:

x- = -7.629394533748002e-07, f(x-) = 5.82076609515839e-13

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 7.629394528751999e-07, f(x+) = 5.820766087535093e-13

Iteration 32:

x- = -3.814697268123002e-07, f(x-) = 1.4551915247425095e-13

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 3.8146972631269984e-07, f(x+) = 1.455191520930861 1e-13

Iteration 33:

x- = -1.907348635310502e-07, f(x-) = 3.637978816620834e-14

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 1.9073486303144983e-07, f(x+) = 3.6379787975625926e-14

Iteration 34:

x- = -9.536743189042519e-08, f(x-) = 9.094947065374886e-15

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 9.536743139082482e-08, f(x+) = 9.09494697008368e-15

Iteration 35:

x- = -4.768371607011268e-08, f(x-) = 2.2737367782551224e-15

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 4.768371557051232e-08, f(x+) = 2.2737367306095192e-15

Iteration 36:

x- = -2.3841858159956432e-08, f(x-) = 5.684342005194811e-16

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 2.384185766035607e-08, f(x+) = 5.684341766966795e-16

Iteration 37:

x- = -1.1920929204878306e-08, f(x-) = 1.4210855310772051e-16

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 1.1920928705277945e-08, f(x+) = 1.4210854119631971e-16

Iteration 38:

x- = -5.960464727339243e-09, f(x-) = 3.552713976585528e-17

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 5.960464227738882e-09, f(x+) = 3.552713381015487e-17

Iteration 39:

x- = -2.980232488569712e-09, f(x-) = 8.881785685926419e-18

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 2.980231988969351e-09, f(x+) = 8.881782708076212e-18

Iteration 40:

x- = -1.4901163691849462e-09, f(x-) = 2.220446793712927e-18

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 1.4901158695845852e-09, f(x+) = 2.220445304787824 3e-18

Iteration 41:

x- = -7.450583094925634e-10, f(x-) = 5.551118845439164e-19

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 7.450578098922023e-10, f(x+) = 5.551111400813651e-19

Iteration 42:

x- = -3.7252927964637197e-10, f(x-) = 1.387780641938448e-19

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 3.725287800460109e-10, f(x+) = 1.3877769196256917e-19

Iteration 43:

x- = -1.8626476472327625e-10, f(x-) = 3.469456257741746e-20

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 1.8626426512291517e-10, f(x+) = 3.4694376461779634e-20

Iteration 44:

x- = -9.31325072617284e-11, f(x-) = 8.673663908855893e-21

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 9.313200766136732e-11, f(x+) = 8.67357085103698e-21

Iteration 45:

x- = -4.656637853095447e-11, f(x-) = 2.1684276094881373e-21

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 4.656587893059339e-11, f(x+) = 2.168381080578681e-21

Iteration 46:

x- = -2.3283314165567505e-11, f(x-) = 5.421127185325164e-22

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 2.3282814565206424e-11, f(x+) = 5.420894540777884e-22

Iteration 47:

x- = -1.1641781982874023e-11, f(x-) = 1.355310877367702e-22

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 1.1641282382512941e-11, f(x+) = 1.3551945550940619e-22

Iteration 48:

x- = -5.821015891527282e-12, f(x-) = 3.3884226009413156e-23

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 5.8205162911662e-12, f(x+) = 3.387840989573114e-23

Iteration 49:

x- = -2.910632845853911e-12, f(x-) = 8.471783563363638e-24

x0 = -2.498001805406602e-16, f(x°) = 6.240013019814644e-32

x+ = 2.91013324549283e-12, f(x+) = 8.468875506522631e-24

Minimaler Wert f(x)= 0.0000 gefunden in xk=-0.00000000

Starte Petras Optimierung für x0=-10, d0=1

Iteration 0:

x- = -11, f(x-) = 121

x0 = -10, f(x°) = 100

x+ = -9, f(x+) = 81

Iteration 1:

x- = -11, f(x-) = 121

x0 = -9, f(x°) = 81

x+ = -7, f(x+) = 49

Iteration 2:

x- = -11, f(x-) = 121

x0 = -7, f(x°) = 49

x+ = -3, f(x+) = 9

Iteration 3:

x- = -11, f(x-) = 121

x0 = -3, f(x°) = 9

x+ = 5, f(x+) = 25

Iteration 4:

x- = -7.0, f(x-) = 49.0

x0 = -3, f(x°) = 9

x+ = 1.0, f(x+) = 1.0

Iteration 5:

x- = -7.0, f(x-) = 49.0

x0 = 1.0, f(x°) = 1.0

x+ = 9.0, f(x+) = 81.0

Iteration 6:

x- = -3.0, f(x-) = 9.0

x0 = 1.0, f(x°) = 1.0

x+ = 5.0, f(x+) = 25.0

Iteration 7:

x- = -1.0, f(x-) = 1.0

x0 = 1.0, f(x°) = 1.0

x+ = 3.0, f(x+) = 9.0

Iteration 8:

x- = 0.0, f(x-) = 0.0

x0 = 1.0, f(x°) = 1.0

x+ = 2.0, f(x+) = 4.0

Iteration 9:

x- = -2.0, f(x-) = 4.0

x0 = 0.0, f(x°) = 0.0

x+ = 2.0, f(x+) = 4.0

Iteration 10:

x- = -1.0, f(x-) = 1.0

x0 = 0.0, f(x°) = 0.0

x+ = 1.0, f(x+) = 1.0

Iteration 11:

x- = -0.5, f(x-) = 0.25

x0 = 0.0, f(x°) = 0.0

x+ = 0.5, f(x+) = 0.25

Iteration 12:

x- = -0.25, f(x-) = 0.0625

x0 = 0.0, f(x°) = 0.0

x+ = 0.25, f(x+) = 0.0625

Iteration 13:

x- = -0.125, f(x-) = 0.015625

x0 = 0.0, f(x°) = 0.0

x+ = 0.125, f(x+) = 0.015625

Iteration 14:

x- = -0.0625, f(x-) = 0.00390625

x0 = 0.0, f(x°) = 0.0

x+ = 0.0625, f(x+) = 0.00390625

Iteration 15:

x- = -0.03125, f(x-) = 0.0009765625

x0 = 0.0, f(x°) = 0.0

x+ = 0.03125, f(x+) = 0.0009765625

Iteration 16:

x- = -0.015625, f(x-) = 0.000244140625

x0 = 0.0, f(x°) = 0.0

x+ = 0.015625, f(x+) = 0.000244140625

Iteration 17:

x- = -0.0078125, f(x-) = 6.103515625e-05

x0 = 0.0, f(x°) = 0.0

x+ = 0.0078125, f(x+) = 6.103515625e-05

Iteration 18:

x- = -0.00390625, f(x-) = 1.52587890625e-05

x0 = 0.0, f(x°) = 0.0

x+ = 0.00390625, f(x+) = 1.52587890625e-05

Iteration 19:

x- = -0.001953125, f(x-) = 3.814697265625e-06

x0 = 0.0, f(x°) = 0.0

x+ = 0.001953125, f(x+) = 3.814697265625e-06

Iteration 20:

x- = -0.0009765625, f(x-) = 9.5367431640625e-07

x0 = 0.0, f(x°) = 0.0

x+ = 0.0009765625, f(x+) = 9.5367431640625e-07

Iteration 21:

x- = -0.00048828125, f(x-) = 2.384185791015625e-07

x0 = 0.0, f(x°) = 0.0

x+ = 0.00048828125, f(x+) = 2.384185791015625e-07

Iteration 22:

x- = -0.000244140625, f(x-) = 5.960464477539063e-08

x0 = 0.0, f(x°) = 0.0

x+ = 0.000244140625, f(x+) = 5.960464477539063e-08

Iteration 23:

x- = -0.0001220703125, f(x-) = 1.4901161193847656e-08

x0 = 0.0, f(x°) = 0.0

x+ = 0.0001220703125, f(x+) = 1.4901161193847656e-08

Iteration 24:

x- = -6.103515625e-05, f(x-) = 3.725290298461914e-09

x0 = 0.0, f(x°) = 0.0

x+ = 6.103515625e-05, f(x+) = 3.725290298461914e-09

Iteration 25:

x- = -3.0517578125e-05, f(x-) = 9.313225746154785e-10

x0 = 0.0, f(x°) = 0.0

x+ = 3.0517578125e-05, f(x+) = 9.313225746154785e-10

Iteration 26:

x- = -1.52587890625e-05, f(x-) = 2.3283064365386963e-10

x0 = 0.0, f(x°) = 0.0

x+ = 1.52587890625e-05, f(x+) = 2.3283064365386963e-10

Iteration 27:

x- = -7.62939453125e-06, f(x-) = 5.820766091346741e-11

x0 = 0.0, f(x°) = 0.0

x+ = 7.62939453125e-06, f(x+) = 5.820766091346741e-11

Iteration 28:

x- = -3.814697265625e-06, f(x-) = 1.4551915228366852e-11

x0 = 0.0, f(x°) = 0.0

x+ = 3.814697265625e-06, f(x+) = 1.4551915228366852e-11

Iteration 29:

x- = -1.9073486328125e-06, f(x-) = 3.637978807091713e-12

x0 = 0.0, f(x°) = 0.0

x+ = 1.9073486328125e-06, f(x+) = 3.637978807091713e-12

Iteration 30:

x- = -9.5367431640625e-07, f(x-) = 9.094947017729282e-13

x0 = 0.0, f(x°) = 0.0

x+ = 9.5367431640625e-07, f(x+) = 9.094947017729282e-13

Iteration 31:

x- = -4.76837158203125e-07, f(x-) = 2.2737367544323206e-13

x0 = 0.0, f(x°) = 0.0

x+ = 4.76837158203125e-07, f(x+) = 2.2737367544323206e-13

Iteration 32:

x- = -2.384185791015625e-07, f(x-) = 5.684341886080802e-14

x0 = 0.0, f(x°) = 0.0

x+ = 2.384185791015625e-07, f(x+) = 5.684341886080802e-14

Iteration 33:

x- = -1.1920928955078125e-07, f(x-) = 1.4210854715202004e-14

x0 = 0.0, f(x°) = 0.0

x+ = 1.1920928955078125e-07, f(x+) = 1.4210854715202004e-14

Iteration 34:

x- = -5.960464477539063e-08, f(x-) = 3.552713678800501e-15

x0 = 0.0, f(x°) = 0.0

x+ = 5.960464477539063e-08, f(x+) = 3.552713678800501e-15

Iteration 35:

x- = -2.9802322387695312e-08, f(x-) = 8.881784197001252e-16

x0 = 0.0, f(x°) = 0.0

x+ = 2.9802322387695312e-08, f(x+) = 8.881784197001252e-16

Iteration 36:

x- = -1.4901161193847656e-08, f(x-) = 2.220446049250313e-16

x0 = 0.0, f(x°) = 0.0

x+ = 1.4901161193847656e-08, f(x+) = 2.220446049250313e-16

Iteration 37:

x- = -7.450580596923828e-09, f(x-) = 5.551115123125783e-17

x0 = 0.0, f(x°) = 0.0

x+ = 7.450580596923828e-09, f(x+) = 5.551115123125783e-17

Iteration 38:

x- = -3.725290298461914e-09, f(x-) = 1.3877787807814457e-17

x0 = 0.0, f(x°) = 0.0

x+ = 3.725290298461914e-09, f(x+) = 1.3877787807814457e-17

Iteration 39:

x- = -1.862645149230957e-09, f(x-) = 3.469446951953614e-18

x0 = 0.0, f(x°) = 0.0

x+ = 1.862645149230957e-09, f(x+) = 3.469446951953614e-18

Iteration 40:

x- = -9.313225746154785e-10, f(x-) = 8.673617379884035e-19

x0 = 0.0, f(x°) = 0.0

x+ = 9.313225746154785e-10, f(x+) = 8.673617379884035e-19

Iteration 41:

x- = -4.656612873077393e-10, f(x-) = 2.168404344971009e-19

x0 = 0.0, f(x°) = 0.0

x+ = 4.656612873077393e-10, f(x+) = 2.168404344971009e-19

Iteration 42:

x- = -2.3283064365386963e-10, f(x-) = 5.421010862427522e-20

x0 = 0.0, f(x°) = 0.0

x+ = 2.3283064365386963e-10, f(x+) = 5.421010862427522e-20

Iteration 43:

x- = -1.1641532182693481e-10, f(x-) = 1.3552527156068805e-20

x0 = 0.0, f(x°) = 0.0

x+ = 1.1641532182693481e-10, f(x+) = 1.3552527156068805e-20

Iteration 44:

x- = -5.820766091346741e-11, f(x-) = 3.3881317890172014e-21

x0 = 0.0, f(x°) = 0.0

x+ = 5.820766091346741e-11, f(x+) = 3.3881317890172014e-21

Iteration 45:

x- = -2.9103830456733704e-11, f(x-) = 8.470329472543003e-22

x0 = 0.0, f(x°) = 0.0

x+ = 2.9103830456733704e-11, f(x+) = 8.470329472543003e-22

Iteration 46:

x- = -1.4551915228366852e-11, f(x-) = 2.117582368135751e-22

x0 = 0.0, f(x°) = 0.0

x+ = 1.4551915228366852e-11, f(x+) = 2.117582368135751e-22

Iteration 47:

x- = -7.275957614183426e-12, f(x-) = 5.293955920339377e-23

x0 = 0.0, f(x°) = 0.0

x+ = 7.275957614183426e-12, f(x+) = 5.293955920339377e-23

Iteration 48:

x- = -3.637978807091713e-12, f(x-) = 1.3234889800848443e-23

x0 = 0.0, f(x°) = 0.0

x+ = 3.637978807091713e-12, f(x+) = 1.3234889800848443e-23

Iteration 49:

x- = -1.8189894035458565e-12, f(x-) = 3.308722450212111e-24

x0 = 0.0, f(x°) = 0.0

x+ = 1.8189894035458565e-12, f(x+) = 3.308722450212111e-24

Minimaler Wert f(x)= 0.0000 gefunden in xk= 0.00000000

Diskussion der Ergebnisse:

Im ersten Durchlauf aus d) wird die Schrittweite im Vergleich zu vorher verringert.

Der Startwert bleibt der gleiche. Das Verfahren benötigt mehr Iterationen um auf den Minimierer zu kommen.

Im zweiten Durchlauf ist die Schrittweite wieder 1, der Startwert jedoch weiter weg vom Minimierer.

Auch hier braucht es mehr Iterationen um auf den Minimierer zu kommen.

Das wählen eines sinnvollen Startwertes und einer geeigneten Schrittweite beschleunigen das Verfahren.

Starte Petras Optimierung für x0=0, d0=1

Iteration 0:

x- = -1, f(x-) = -3

x0 = 0, f(x°) = 0

x+ = 1, f(x+) = -3

Iteration 1:

x- = 0.5, f(x-) = -0.9375

x0 = 1, f(x°) = -3

x+ = 1.5, f(x+) = -3.9375

Iteration 2:

x- = 0.5, f(x-) = -0.9375

x0 = 1.5, f(x°) = -3.9375

x+ = 2.5, f(x+) = 14.0625

Iteration 3:

x- = 1.0, f(x-) = -3.0

x0 = 1.5, f(x°) = -3.9375

x+ = 2.0, f(x+) = 0.0

Iteration 4:

x- = 1.25, f(x-) = -3.80859375

x0 = 1.5, f(x°) = -3.9375

x+ = 1.75, f(x+) = -2.87109375

Iteration 5:

x- = 1.375, f(x-) = -3.988037109375

x0 = 1.5, f(x°) = -3.9375

x+ = 1.625, f(x+) = -3.589599609375

Iteration 6:

x- = 1.125, f(x-) = -3.460693359375

x0 = 1.375, f(x°) = -3.988037109375

x+ = 1.625, f(x+) = -3.589599609375

Iteration 7:

x- = 1.25, f(x-) = -3.80859375

x0 = 1.375, f(x°) = -3.988037109375

x+ = 1.5, f(x+) = -3.9375

Iteration 8:

x- = 1.3125, f(x-) = -3.9230804443359375

x0 = 1.375, f(x°) = -3.988037109375

x+ = 1.4375, f(x+) = -3.9955902099609375

Iteration 9:

x- = 1.3125, f(x-) = -3.9230804443359375

x0 = 1.4375, f(x°) = -3.9955902099609375

x+ = 1.5625, f(x+) = -3.8051605224609375

Iteration 10:

x- = 1.375, f(x-) = -3.988037109375

x0 = 1.4375, f(x°) = -3.9955902099609375

x+ = 1.5, f(x+) = -3.9375

Iteration 11:

x- = 1.40625, f(x-) = -3.999495506286621

x0 = 1.4375, f(x°) = -3.9955902099609375

x+ = 1.46875, f(x+) = -3.9752798080444336

Iteration 12:

x- = 1.34375, f(x-) = -3.962233543395996

x0 = 1.40625, f(x°) = -3.999495506286621

x+ = 1.46875, f(x+) = -3.9752798080444336

Iteration 13:

x- = 1.375, f(x-) = -3.988037109375

x0 = 1.40625, f(x°) = -3.999495506286621

x+ = 1.4375, f(x+) = -3.9955902099609375

Iteration 14:

x- = 1.390625, f(x-) = -3.9956225752830505

x0 = 1.40625, f(x°) = -3.999495506286621

x+ = 1.421875, f(x+) = -3.999527871608734

Iteration 15:

x- = 1.390625, f(x-) = -3.9956225752830505

x0 = 1.421875, f(x°) = -3.999527871608734

x+ = 1.453125, f(x+) = -3.9875516295433044

Iteration 16:

x- = 1.40625, f(x-) = -3.999495506286621

x0 = 1.421875, f(x°) = -3.999527871608734

x+ = 1.4375, f(x+) = -3.9955902099609375

Iteration 17:

x- = 1.4140625, f(x-) = -3.9999998174607754

x0 = 1.421875, f(x°) = -3.999527871608734

x+ = 1.4296875, f(x+) = -3.9980634413659573

Iteration 18:

x- = 1.3984375, f(x-) = -3.9980310760438442

x0 = 1.4140625, f(x°) = -3.9999998174607754

x+ = 1.4296875, f(x+) = -3.9980634413659573

Iteration 19:

x- = 1.40625, f(x-) = -3.999495506286621

x0 = 1.4140625, f(x°) = -3.9999998174607754

x+ = 1.421875, f(x+) = -3.999527871608734

Iteration 20:

x- = 1.41015625, f(x-) = -3.9998686832841486

x0 = 1.4140625, f(x°) = -3.9999998174607754

x+ = 1.41796875, f(x+) = -3.999886888777837

Iteration 21:

x- = 1.412109375, f(x-) = -3.999964631846524

x0 = 1.4140625, f(x°) = -3.9999998174607754

x+ = 1.416015625, f(x+) = -3.999973987447447

Iteration 22:

x- = 1.4130859375, f(x-) = -3.9999898358064456

x0 = 1.4140625, f(x°) = -3.9999998174607754

x+ = 1.4150390625, f(x+) = -3.999994545213667

Iteration 23:

x- = 1.41357421875, f(x-) = -3.9999967313960383

x0 = 1.4140625, f(x°) = -3.9999998174607754

x+ = 1.41455078125, f(x+) = -3.999999090050494

Iteration 24:

x- = 1.413818359375, f(x-) = -3.999998750865867

x0 = 1.4140625, f(x°) = -3.9999998174607754

x+ = 1.414306640625, f(x+) = -3.9999999306869505

Iteration 25:

x- = 1.413818359375, f(x-) = -3.999998750865867

x0 = 1.414306640625, f(x°) = -3.9999999306869505

x+ = 1.414794921875, f(x+) = -3.9999972950574225

Iteration 26:

x- = 1.4140625, f(x-) = -3.9999998174607754

x0 = 1.414306640625, f(x°) = -3.9999999306869505

x+ = 1.41455078125, f(x+) = -3.999999090050494

Iteration 27:

x- = 1.4141845703125, f(x-) = -3.9999999932758215

x0 = 1.414306640625, f(x°) = -3.9999999306869505

x+ = 1.4144287109375, f(x+) = -3.9999996296324234

Iteration 28:

x- = 1.4139404296875, f(x-) = -3.9999994033035478

x0 = 1.4141845703125, f(x°) = -3.9999999932758215

x+ = 1.4144287109375, f(x+) = -3.9999996296324234

Iteration 29:

x- = 1.4140625, f(x-) = -3.9999998174607754

x0 = 1.4141845703125, f(x°) = -3.9999999932758215

x+ = 1.414306640625, f(x+) = -3.9999999306869505

Iteration 30:

x- = 1.41412353515625, f(x-) = -3.9999999351649294

x0 = 1.4141845703125, f(x°) = -3.9999999932758215

x+ = 1.41424560546875, f(x+) = -3.9999999917857343

Iteration 31:

x- = 1.414154052734375, f(x-) = -3.9999999716700154

x0 = 1.4141845703125, f(x°) = -3.9999999932758215

x+ = 1.414215087890625, f(x+) = -3.999999999981382

Iteration 32:

x- = 1.414154052734375, f(x-) = -3.9999999716700154

x0 = 1.414215087890625, f(x°) = -3.999999999981382

x+ = 1.414276123046875, f(x+) = -3.999999968687912

Iteration 33:

x- = 1.4141845703125, f(x-) = -3.9999999932758215

x0 = 1.414215087890625, f(x°) = -3.999999999981382

x+ = 1.41424560546875, f(x+) = -3.9999999917857343

Iteration 34:

x- = 1.4141998291015625, f(x-) = -3.9999999984911927

x0 = 1.4142150878906250, f(x°) = -3.999999999981382

x+ = 1.4142303466796875, f(x+) = -3.9999999977462695

Iteration 35:

x- = 1.4142074584960938, f(x-) = -3.999999999701943

x0 = 1.4142150878906250, f(x°) = -3.999999999981382

x+ = 1.4142227172851562, f(x+) = -3.9999999993294963

Iteration 36:

x- = 1.4142112731933594, f(x-) = -3.9999999999580775

x0 = 1.4142150878906250, f(x°) = -3.999999999981382

x+ = 1.4142189025878906, f(x+) = -3.9999999997718563

Iteration 37:

x- = 1.4142131805419922, f(x-) = -3.999999999998834

x0 = 1.4142150878906250, f(x°) = -3.999999999981382

x+ = 1.4142169952392578, f(x+) = -3.9999999999057234

Iteration 38:

x- = 1.4142093658447266, f(x-) = -3.9999999998591136

x0 = 1.4142131805419922, f(x°) = -3.999999999998834

x+ = 1.4142169952392578, f(x+) = -3.9999999999057234

Iteration 39:

x- = 1.4142112731933594, f(x-) = -3.9999999999580775

x0 = 1.4142131805419922, f(x°) = -3.999999999998834

x+ = 1.4142150878906250, f(x+) = -3.999999999981382

Iteration 40:

x- = 1.4142122268676758, f(x-) = -3.9999999999857314

x0 = 1.4142131805419922, f(x°) = -3.999999999998834

x+ = 1.4142141342163086, f(x+) = -3.9999999999973843

Iteration 41:

x- = 1.4142127037048340, f(x-) = -3.9999999999941016

x0 = 1.4142131805419922, f(x°) = -3.999999999998834

x+ = 1.4142136573791504, f(x+) = -3.999999999999928

Iteration 42:

x- = 1.4142127037048340, f(x-) = -3.9999999999941016

x0 = 1.4142136573791504, f(x°) = -3.999999999999928

x+ = 1.4142146110534668, f(x+) = -3.9999999999912026

Iteration 43:

x- = 1.4142131805419922, f(x-) = -3.999999999998834

x0 = 1.4142136573791504, f(x°) = -3.999999999999928

x+ = 1.4142141342163086, f(x+) = -3.9999999999973843

Iteration 44:

x- = 1.4142134189605713, f(x-) = -3.9999999999998352

x0 = 1.4142136573791504, f(x°) = -3.999999999999928

x+ = 1.4142138957977295, f(x+) = -3.999999999999111

Iteration 45:

x- = 1.4142135381698608, f(x-) = -3.999999999999995

x0 = 1.4142136573791504, f(x°) = -3.999999999999928

x+ = 1.41421377658844, f(x+) = -3.999999999999633

Iteration 46:

x- = 1.4142132997512817, f(x-) = -3.9999999999994484

x0 = 1.4142135381698608, f(x°) = -3.999999999999995

x+ = 1.41421377658844, f(x+) = -3.999999999999633

Iteration 47:

x- = 1.4142134189605713, f(x-) = -3.9999999999998352

x0 = 1.4142135381698608, f(x°) = -3.999999999999995

x+ = 1.4142136573791504, f(x+) = -3.999999999999928

Iteration 48:

x- = 1.414213478565216, f(x-) = -3.9999999999999436

x0 = 1.4142135381698608, f(x°) = -3.999999999999995

x+ = 1.4142135977745056, f(x+) = -3.9999999999999902

Iteration 49:

x- = 1.4142135083675385, f(x-) = -3.9999999999999765

x0 = 1.4142135381698608, f(x°) = -3.999999999999995

x+ = 1.4142135679721832, f(x+) = -4.0

Minimaler Wert f(x)=-4.0000 gefunden in xk= 1.41421357

Starte Petras Optimierung für x0=0, d0=1

Iteration 0:

x- = -1, f(x-) = -1

x0 = 0, f(x°) = 0

x+ = 1, f(x+) = 1

Iteration 1:

x- = -3, f(x-) = -3

x0 = -1, f(x°) = -1

x+ = 1, f(x+) = 1

Iteration 2:

x- = -7, f(x-) = -7

x0 = -3, f(x°) = -3

x+ = 1, f(x+) = 1

Iteration 3:

x- = -15, f(x-) = -15

x0 = -7, f(x°) = -7

x+ = 1, f(x+) = 1

Iteration 4:

x- = -31, f(x-) = -31

x0 = -15, f(x°) = -15

x+ = 1, f(x+) = 1

Iteration 5:

x- = -63, f(x-) = -63

x0 = -31, f(x°) = -31

x+ = 1, f(x+) = 1

Iteration 6:

x- = -127, f(x-) = -127

x0 = -63, f(x°) = -63

x+ = 1, f(x+) = 1

Iteration 7:

x- = -255, f(x-) = -255

x0 = -127, f(x°) = -127

x+ = 1, f(x+) = 1

Iteration 8:

x- = -511, f(x-) = -511

x0 = -255, f(x°) = -255

x+ = 1, f(x+) = 1

Iteration 9:

x- = -1023, f(x-) = -1023

x0 = -511, f(x°) = -511

x+ = 1, f(x+) = 1

Iteration 10:

x- = -2047, f(x-) = -2047

x0 = -1023, f(x°) = -1023

x+ = 1, f(x+) = 1

Iteration 11:

x- = -4095, f(x-) = -4095

x0 = -2047, f(x°) = -2047

x+ = 1, f(x+) = 1

Iteration 12:

x- = -8191, f(x-) = -8191

x0 = -4095, f(x°) = -4095

x+ = 1, f(x+) = 1

Iteration 13:

x- = -16383, f(x-) = -16383

x0 = -8191, f(x°) = -8191

x+ = 1, f(x+) = 1

Iteration 14:

x- = -32767, f(x-) = -32767

x0 = -16383, f(x°) = -16383

x+ = 1, f(x+) = 1

Iteration 15:

x- = -65535, f(x-) = -65535

x0 = -32767, f(x°) = -32767

x+ = 1, f(x+) = 1

Iteration 16:

x- = -131071, f(x-) = -131071

x0 = -65535, f(x°) = -65535

x+ = 1, f(x+) = 1

Iteration 17:

x- = -262143, f(x-) = -262143

x0 = -131071, f(x°) = -131071

x+ = 1, f(x+) = 1

Iteration 18:

x- = -524287, f(x-) = -524287

x0 = -262143, f(x°) = -262143

x+ = 1, f(x+) = 1

Iteration 19:

x- = -1048575, f(x-) = -1048575

x0 = -524287, f(x°) = -524287

x+ = 1, f(x+) = 1

Iteration 20:

x- = -2097151, f(x-) = -2097151

x0 = -1048575, f(x°) = -1048575

x+ = 1, f(x+) = 1

Iteration 21:

x- = -4194303, f(x-) = -4194303

x0 = -2097151, f(x°) = -2097151

x+ = 1, f(x+) = 1

Iteration 22:

x- = -8388607, f(x-) = -8388607

x0 = -4194303, f(x°) = -4194303

x+ = 1, f(x+) = 1

Iteration 23:

x- = -16777215, f(x-) = -16777215

x0 = -8388607, f(x°) = -8388607

x+ = 1, f(x+) = 1

Iteration 24:

x- = -33554431, f(x-) = -33554431

x0 = -16777215, f(x°) = -16777215

x+ = 1, f(x+) = 1

Iteration 25:

x- = -67108863, f(x-) = -67108863

x0 = -33554431, f(x°) = -33554431

x+ = 1, f(x+) = 1

Iteration 26:

x- = -134217727, f(x-) = -134217727

x0 = -67108863, f(x°) = -67108863

x+ = 1, f(x+) = 1

Iteration 27:

x- = -268435455, f(x-) = -268435455

x0 = -134217727, f(x°) = -134217727

x+ = 1, f(x+) = 1

Iteration 28:

x- = -536870911, f(x-) = -536870911

x0 = -268435455, f(x°) = -268435455

x+ = 1, f(x+) = 1

Iteration 29:

x- = -1073741823, f(x-) = -1073741823

x0 = -536870911, f(x°) = -536870911

x+ = 1, f(x+) = 1

Iteration 30:

x- = -2147483647, f(x-) = -2147483647

x0 = -1073741823, f(x°) = -1073741823

x+ = 1, f(x+) = 1

Iteration 31:

x- = -4294967295, f(x-) = -4294967295

x0 = -2147483647, f(x°) = -2147483647

x+ = 1, f(x+) = 1

Iteration 32:

x- = -8589934591, f(x-) = -8589934591

x0 = -4294967295, f(x°) = -4294967295

x+ = 1, f(x+) = 1

Iteration 33:

x- = -17179869183, f(x-) = -17179869183

x0 = -8589934591, f(x°) = -8589934591

x+ = 1, f(x+) = 1

Iteration 34:

x- = -34359738367, f(x-) = -34359738367

x0 = -17179869183, f(x°) = -17179869183

x+ = 1, f(x+) = 1

Iteration 35:

x- = -68719476735, f(x-) = -68719476735

x0 = -34359738367, f(x°) = -34359738367

x+ = 1, f(x+) = 1

Iteration 36:

x- = -137438953471, f(x-) = -137438953471

x0 = -68719476735, f(x°) = -68719476735

x+ = 1, f(x+) = 1

Iteration 37:

x- = -274877906943, f(x-) = -274877906943

x0 = -137438953471, f(x°) = -137438953471

x+ = 1, f(x+) = 1

Iteration 38:

x- = -549755813887, f(x-) = -549755813887

x0 = -274877906943, f(x°) = -274877906943

x+ = 1, f(x+) = 1

Iteration 39:

x- = -1099511627775, f(x-) = -1099511627775

x0 = -549755813887, f(x°) = -549755813887

x+ = 1, f(x+) = 1

Iteration 40:

x- = -2199023255551, f(x-) = -2199023255551

x0 = -1099511627775, f(x°) = -1099511627775

x+ = 1, f(x+) = 1

Iteration 41:

x- = -4398046511103, f(x-) = -4398046511103

x0 = -2199023255551, f(x°) = -2199023255551

x+ = 1, f(x+) = 1

Iteration 42:

x- = -8796093022207, f(x-) = -8796093022207

x0 = -4398046511103, f(x°) = -4398046511103

x+ = 1, f(x+) = 1

Iteration 43:

x- = -17592186044415, f(x-) = -17592186044415

x0 = -8796093022207, f(x°) = -8796093022207

x+ = 1, f(x+) = 1

Iteration 44:

x- = -35184372088831, f(x-) = -35184372088831

x0 = -17592186044415, f(x°) = -17592186044415

x+ = 1, f(x+) = 1

Iteration 45:

x- = -70368744177663, f(x-) = -70368744177663

x0 = -35184372088831, f(x°) = -35184372088831

x+ = 1, f(x+) = 1

Iteration 46:

x- = -140737488355327, f(x-) = -140737488355327

x0 = -70368744177663, f(x°) = -70368744177663

x+ = 1, f(x+) = 1

Iteration 47:

x- = -281474976710655, f(x-) = -281474976710655

x0 = -140737488355327, f(x°) = -140737488355327

x+ = 1, f(x+) = 1

Iteration 48:

x- = -562949953421311, f(x-) = -562949953421311

x0 = -281474976710655, f(x°) = -281474976710655

x+ = 1, f(x+) = 1

Iteration 49:

x- = -1125899906842623, f(x-) = -1125899906842623

x0 = -562949953421311, f(x°) = -562949953421311

x+ = 1, f(x+) = 1

Minimaler Wert f(x)=-1125899906842623.0000 gefunden in xk=-1125899906842623.00000000

Starte Petras Optimierung für x0=1, d0=2

Iteration 0:

x- = -1, f(x-) = -0.5

x0 = 1, f(x°) = -0.5

x+ = 3, f(x+) = -0.9

Iteration 1:

x- = -1, f(x-) = -0.5

x0 = 3, f(x°) = -0.9

x+ = 7, f(x+) = -0.98

Iteration 2:

x- = -1, f(x-) = -0.5

x0 = 7, f(x°) = -0.98

x+ = 15, f(x+) = -0.995575221238938

Iteration 3:

x- = -1, f(x-) = -0.5

x0 = 15, f(x°) = -0.995575221238938

x+ = 31, f(x+) = -0.998960498960499

Iteration 4:

x- = -1, f(x-) = -0.5

x0 = 31, f(x°) = -0.998960498960499

x+ = 63, f(x+) = -0.9997481108312343

Iteration 5:

x- = -1, f(x-) = -0.5

x0 = 63, f(x°) = -0.9997481108312343

x+ = 127, f(x+) = -0.9999380037197768

Iteration 6:

x- = -1, f(x-) = -0.5

x0 = 127, f(x°) = -0.9999380037197768

x+ = 255, f(x+) = -0.999984621536001

Iteration 7:

x- = -1, f(x-) = -0.5

x0 = 255, f(x°) = -0.999984621536001

x+ = 511, f(x+) = -0.9999961703724696

Iteration 8:

x- = -1, f(x-) = -0.5

x0 = 511, f(x°) = -0.9999961703724696

x+ = 1023, f(x+) = -0.9999990444612195

Iteration 9:

x- = -1, f(x-) = -0.5

x0 = 1023, f(x°) = -0.9999990444612195

x+ = 2047, f(x+) = -0.9999997613484766

Iteration 10:

x- = -1, f(x-) = -0.5

x0 = 2047, f(x°) = -0.9999997613484766

x+ = 4095, f(x+) = -0.9999999403662443

Iteration 11:

x- = -1, f(x-) = -0.5

x0 = 4095, f(x°) = -0.9999999403662443

x+ = 8191, f(x+) = -0.9999999850952004

Iteration 12:

x- = -1, f(x-) = -0.5

x0 = 8191, f(x°) = -0.9999999850952004

x+ = 16383, f(x+) = -0.999999996274255

Iteration 13:

x- = -1, f(x-) = -0.5

x0 = 16383, f(x°) = -0.999999996274255

x+ = 32767, f(x+) = -0.9999999990686206

Iteration 14:

x- = -1, f(x-) = -0.5

x0 = 32767, f(x°) = -0.9999999990686206

x+ = 65535, f(x+) = -0.9999999997671623

Iteration 15:

x- = -1, f(x-) = -0.5

x0 = 65535, f(x°) = -0.9999999997671623

x+ = 131071, f(x+) = -0.9999999999417915

Iteration 16:

x- = -1, f(x-) = -0.5

x0 = 131071, f(x°) = -0.9999999999417915

x+ = 262143, f(x+) = -0.999999999985448

Iteration 17:

x- = -1, f(x-) = -0.5

x0 = 262143, f(x°) = -0.999999999985448

x+ = 524287, f(x+) = -0.999999999996362

Iteration 18:

x- = -1, f(x-) = -0.5

x0 = 524287, f(x°) = -0.999999999996362

x+ = 1048575, f(x+) = -0.9999999999990905

Iteration 19:

x- = -1, f(x-) = -0.5

x0 = 1048575, f(x°) = -0.9999999999990905

x+ = 2097151, f(x+) = -0.9999999999997726

Iteration 20:

x- = -1, f(x-) = -0.5

x0 = 2097151, f(x°) = -0.9999999999997726

x+ = 4194303, f(x+) = -0.9999999999999432

Iteration 21:

x- = -1, f(x-) = -0.5

x0 = 4194303, f(x°) = -0.9999999999999432

x+ = 8388607, f(x+) = -0.9999999999999858

Iteration 22:

x- = -1, f(x-) = -0.5

x0 = 8388607, f(x°) = -0.9999999999999858

x+ = 16777215, f(x+) = -0.9999999999999964

Iteration 23:

x- = -1, f(x-) = -0.5

x0 = 16777215, f(x°) = -0.9999999999999964

x+ = 33554431, f(x+) = -0.9999999999999991

Iteration 24:

x- = -1, f(x-) = -0.5

x0 = 33554431, f(x°) = -0.9999999999999991

x+ = 67108863, f(x+) = -0.9999999999999998

Iteration 25:

x- = -1, f(x-) = -0.5

x0 = 67108863, f(x°) = -0.9999999999999998

x+ = 134217727, f(x+) = -0.9999999999999989

Iteration 26:

x- = 33554431.0, f(x-) = -0.9999999999999991

x0 = 67108863, f(x°) = -0.9999999999999998

x+ = 100663295.0, f(x+) = -0.9999999999999991

Iteration 27:

x- = 50331647.0, f(x-) = -0.9999999999999996

x0 = 67108863, f(x°) = -0.9999999999999998

x+ = 83886079.0, f(x+) = -0.9999999999999999

Iteration 28:

x- = 50331647.0, f(x-) = -0.9999999999999996

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 117440511.0, f(x+) = -0.999999999999999

Iteration 29:

x- = 67108863.0, f(x-) = -0.9999999999999998

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 100663295.0, f(x+) = -0.9999999999999991

Iteration 30:

x- = 75497471.0, f(x-) = -0.9999999999999998

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 92274687.0, f(x+) = -0.9999999999999999

Iteration 31:

x- = 79691775.0, f(x-) = -0.9999999999999997

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 88080383.0, f(x+) = -0.9999999999999996

Iteration 32:

x- = 81788927.0, f(x-) = -0.9999999999999998

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 85983231.0, f(x+) = -0.9999999999999999

Iteration 33:

x- = 82837503.0, f(x-) = -0.9999999999999999

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 84934655.0, f(x+) = -0.9999999999999997

Iteration 34:

x- = 83361791.0, f(x-) = -0.9999999999999999

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 84410367.0, f(x+) = -0.9999999999999998

Iteration 35:

x- = 83623935.0, f(x-) = -0.9999999999999999

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 84148223.0, f(x+) = -0.9999999999999998

Iteration 36:

x- = 83755007.0, f(x-) = -0.9999999999999997

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 84017151.0, f(x+) = -0.9999999999999996

Iteration 37:

x- = 83820543.0, f(x-) = -0.9999999999999999

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83951615.0, f(x+) = -0.9999999999999998

Iteration 38:

x- = 83853311.0, f(x-) = -0.9999999999999997

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83918847.0, f(x+) = -0.9999999999999999

Iteration 39:

x- = 83869695.0, f(x-) = -0.9999999999999998

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83902463.0, f(x+) = -0.9999999999999999

Iteration 40:

x- = 83877887.0, f(x-) = -0.9999999999999999

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83894271.0, f(x+) = -0.9999999999999997

Iteration 41:

x- = 83881983.0, f(x-) = -0.9999999999999998

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83890175.0, f(x+) = -0.9999999999999999

Iteration 42:

x- = 83884031.0, f(x-) = -0.9999999999999999

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83888127.0, f(x+) = -0.9999999999999997

Iteration 43:

x- = 83885055.0, f(x-) = -0.9999999999999999

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83887103.0, f(x+) = -0.9999999999999998

Iteration 44:

x- = 83885567.0, f(x-) = -0.9999999999999999

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83886591.0, f(x+) = -0.9999999999999998

Iteration 45:

x- = 83885823.0, f(x-) = -0.9999999999999999

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83886335.0, f(x+) = -0.9999999999999999

Iteration 46:

x- = 83885951.0, f(x-) = -0.9999999999999997

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83886207.0, f(x+) = -0.9999999999999996

Iteration 47:

x- = 83886015.0, f(x-) = -0.9999999999999999

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83886143.0, f(x+) = -0.9999999999999998

Iteration 48:

x- = 83886047.0, f(x-) = -0.9999999999999999

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83886111.0, f(x+) = -0.9999999999999998

Iteration 49:

x- = 83886063.0, f(x-) = -0.9999999999999999

x0 = 83886079.0, f(x°) = -0.9999999999999999

x+ = 83886095.0, f(x+) = -0.9999999999999999

Minimaler Wert f(x)=-1.0000 gefunden in xk= 83886079.00000000

Diskussion der Ergebnisse:

Bei $f(x) = x$ lässt sich kein Minimierer finden, weshalb die Schrittweite sich immer verdoppelt.

Offensiochtlich kann kein Minimierer gefunden werden, was sich aber nicht durch ausschließliches anwenden des Verfahren zeigen lassen könnte.

Bei $f(x) = cos(pi * x) + 1/(1 + x * *2)$ hat bei zwei lokalen Minima das mit Betragsmäßig größerem x-Wert

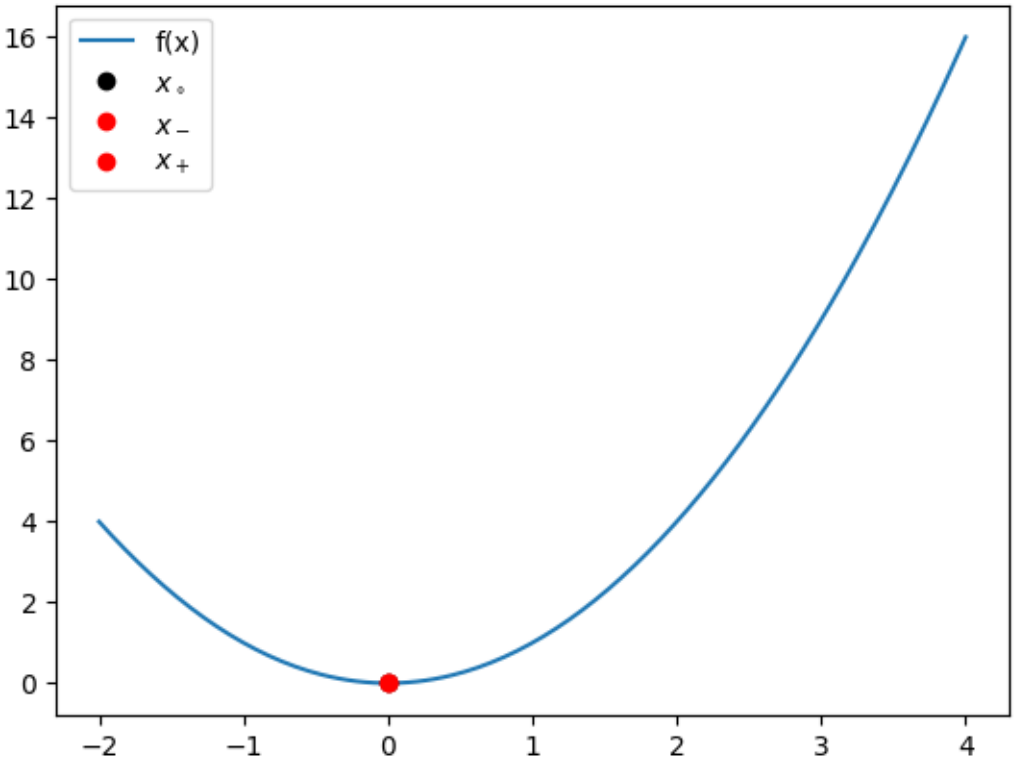
auch einen niedrigeren Funktionswert. Daher findet sich immerwieder ein besserer Wert je weiter die Iterationen durchlaufen.

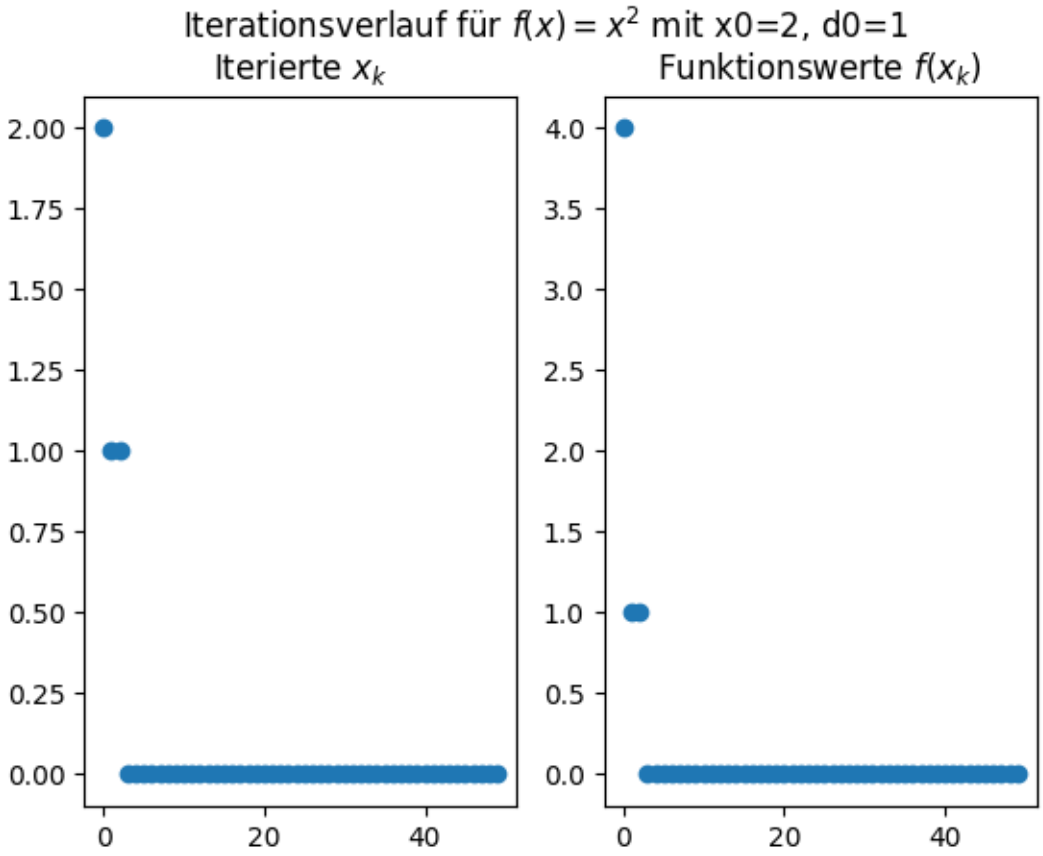
Auch hier mit immer größeren Schrittweiten, bis dann die Maschinengenauigkeit erreicht ist. Dann sinkt die Schrittweite wieder.

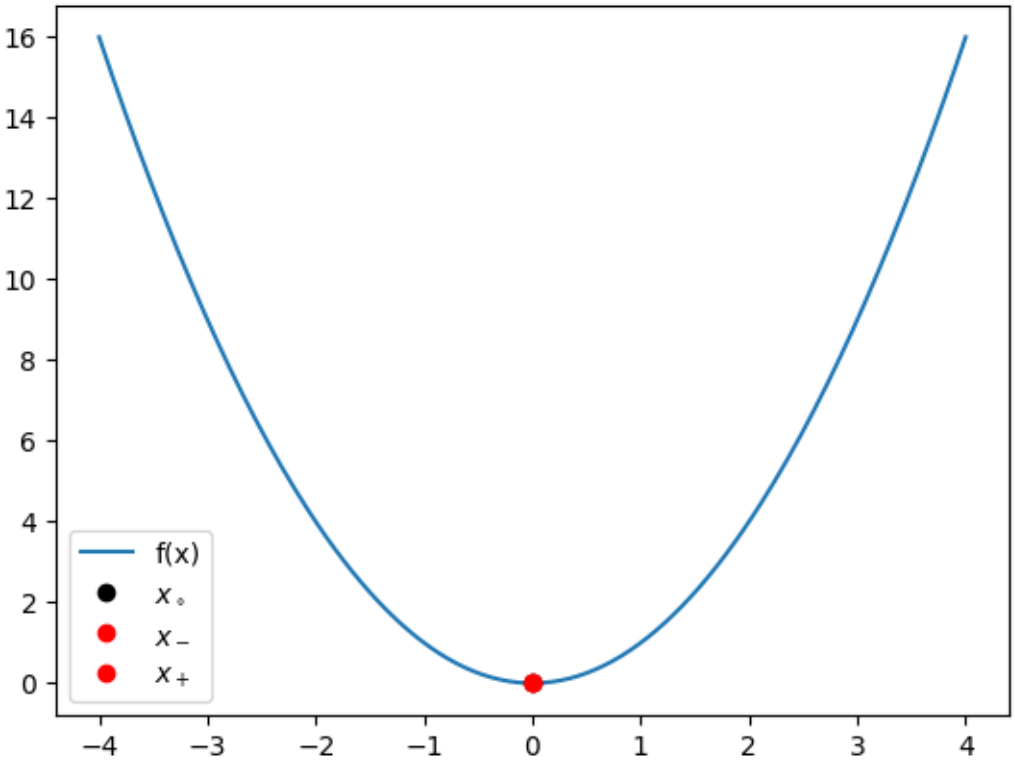
Der innerhalb der Maschinenzahlen beste Minimierer wurde gefunden.Der wesentliche Unterschied zwischen den beiden Beispielen ist, dass das die Minima bei der zweiten Funktionen augenscheinlich konvergieren während bei der ersten Funktion dies nicht der Fall ist.

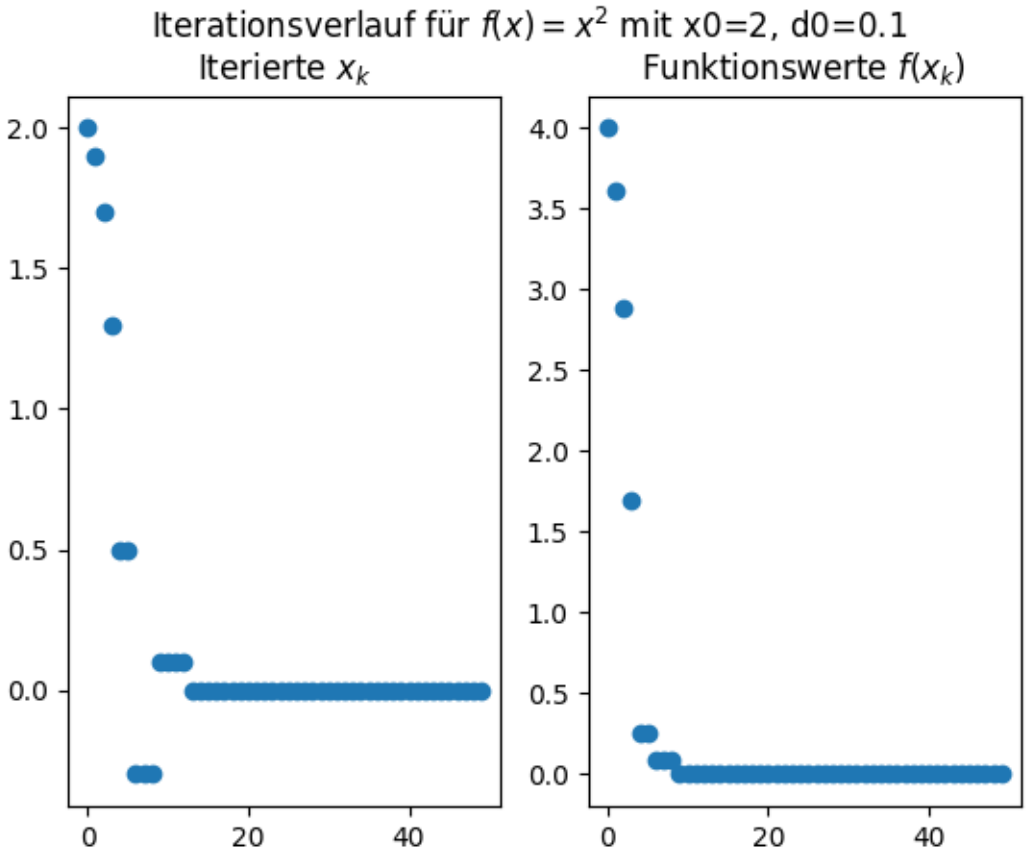
Somit kann zumindest bei der zweiten Funktion der Algorithmus einen nicht ganz 'unsinnigen' Wert bestimmen

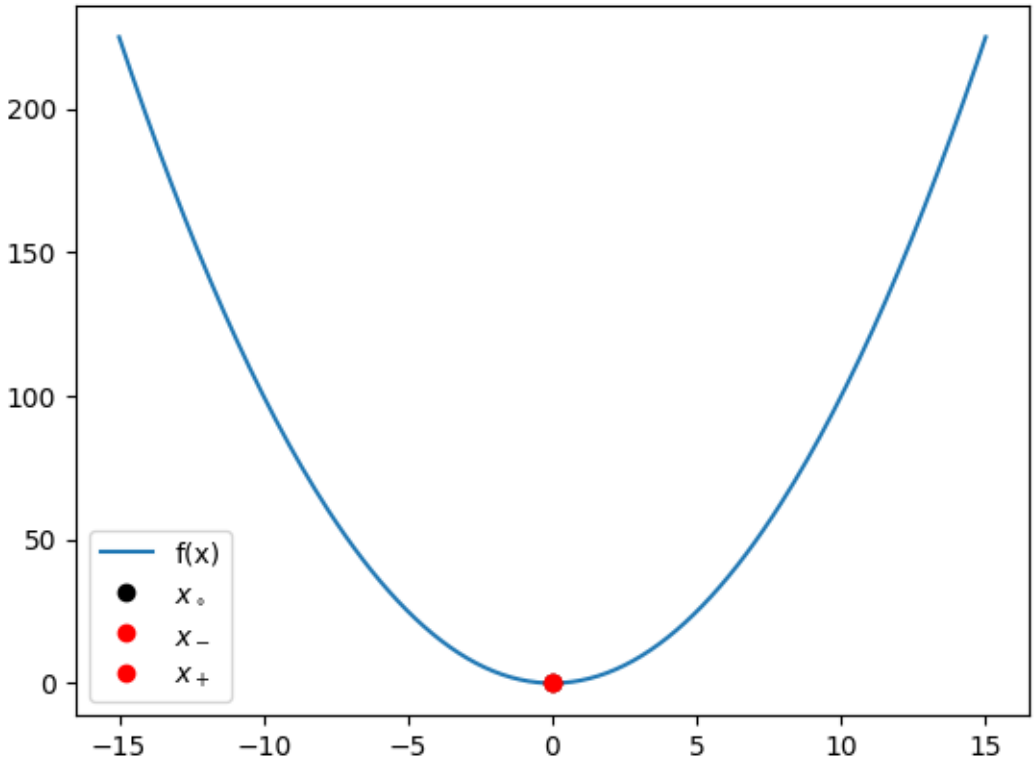
```
#PLOTS:
```

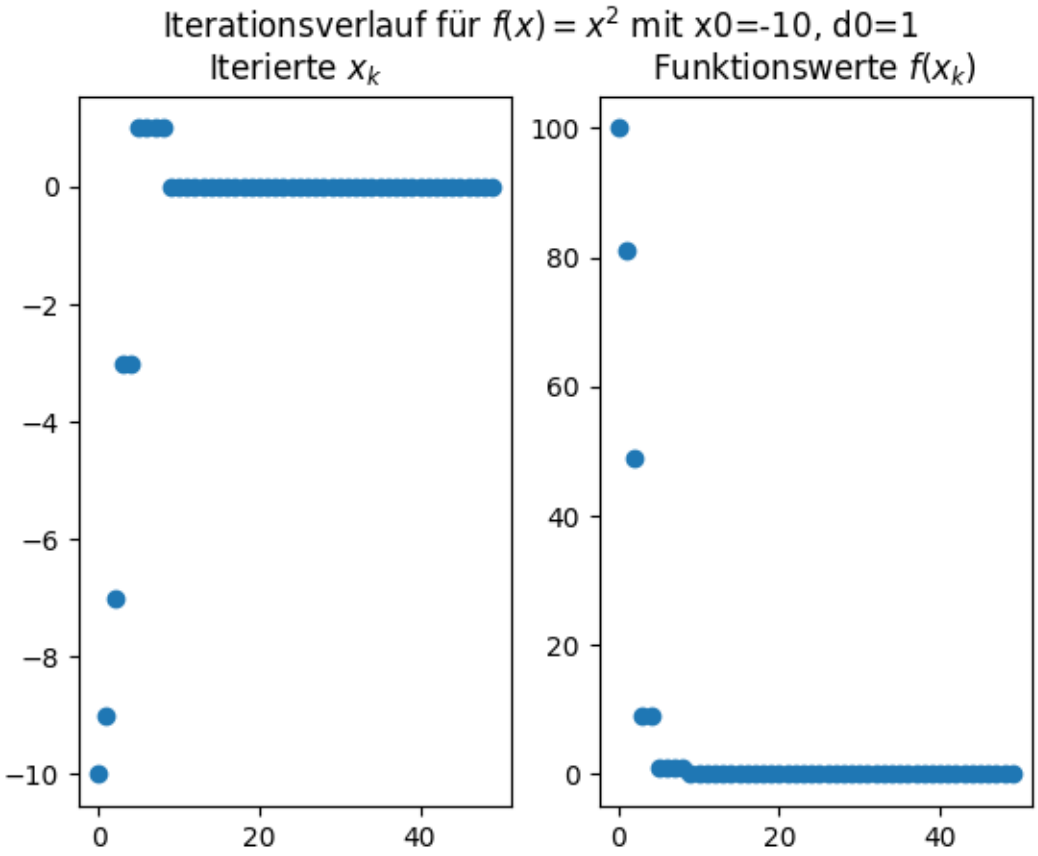

f(x)
$x_\circ$
x_-
x_+
16
14
12
10
8
6
4
2
0
−2
−1
0
1
2
3
4

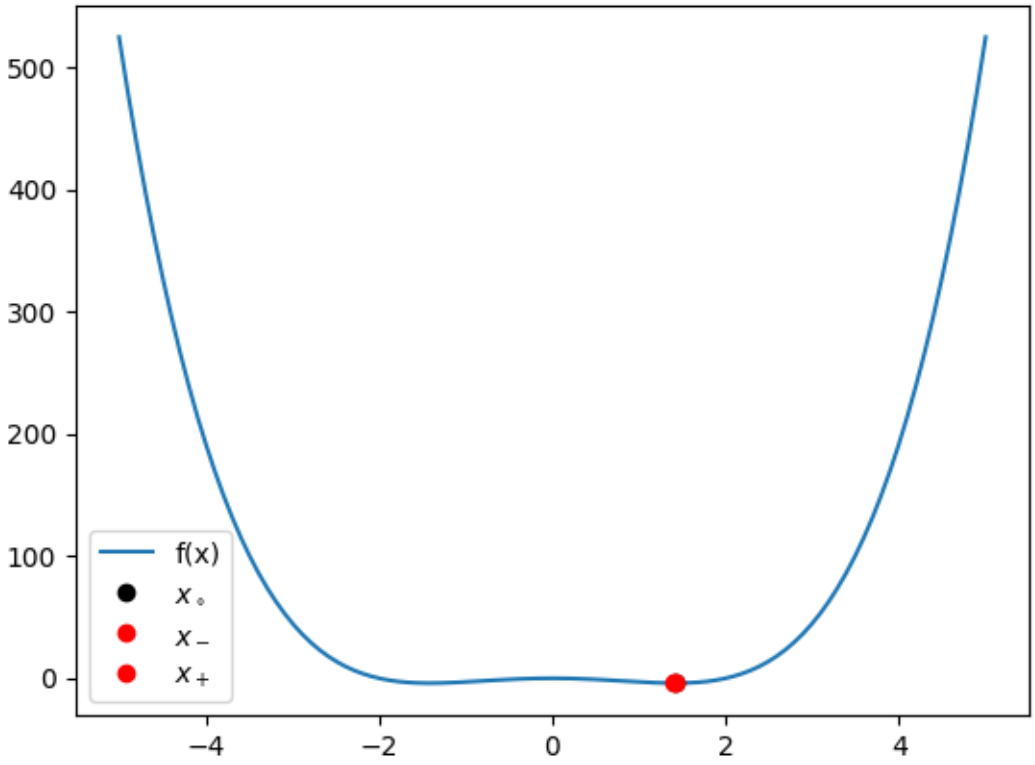

Iterationsverlauf für $f(x) = x^2$ mit x0=2, d0=1
Iterierte x_k
Funktionswerte $f(x_k)$
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
0
20
40

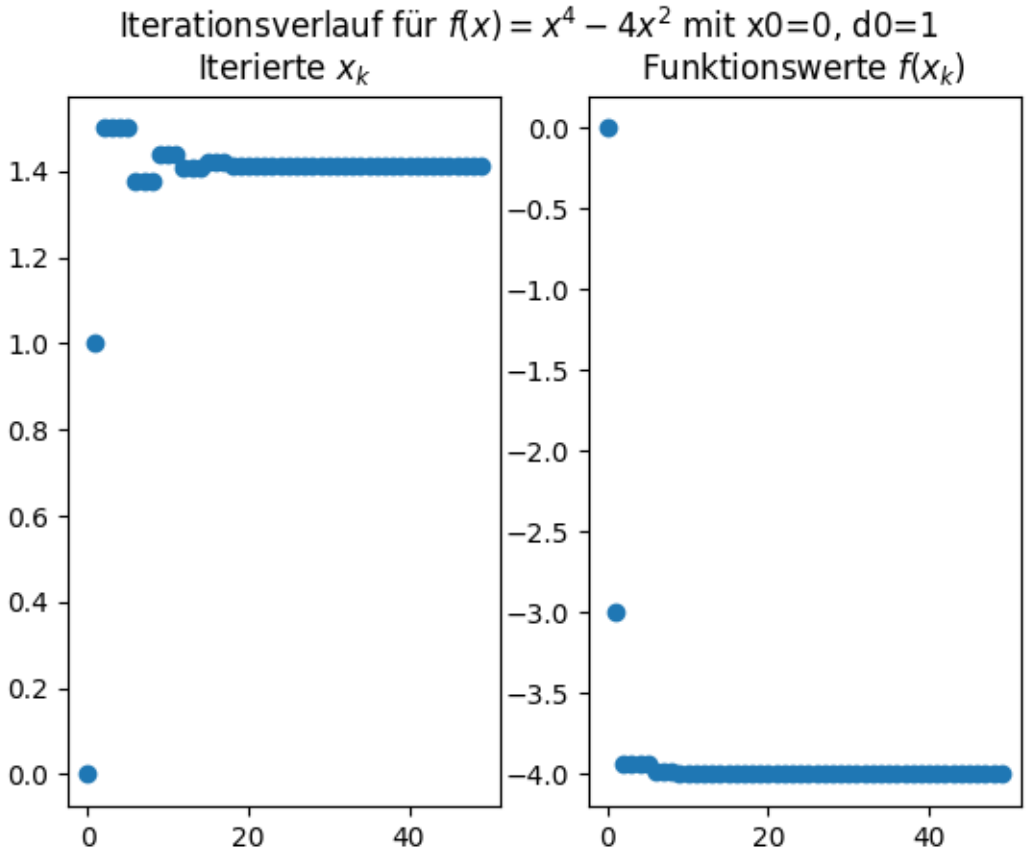

16
14
12
10
8
6
4
2
0
−4
−3
−2
−1
0
1
2
3
4
f(x)
$x_\circ$
x_-
x_+

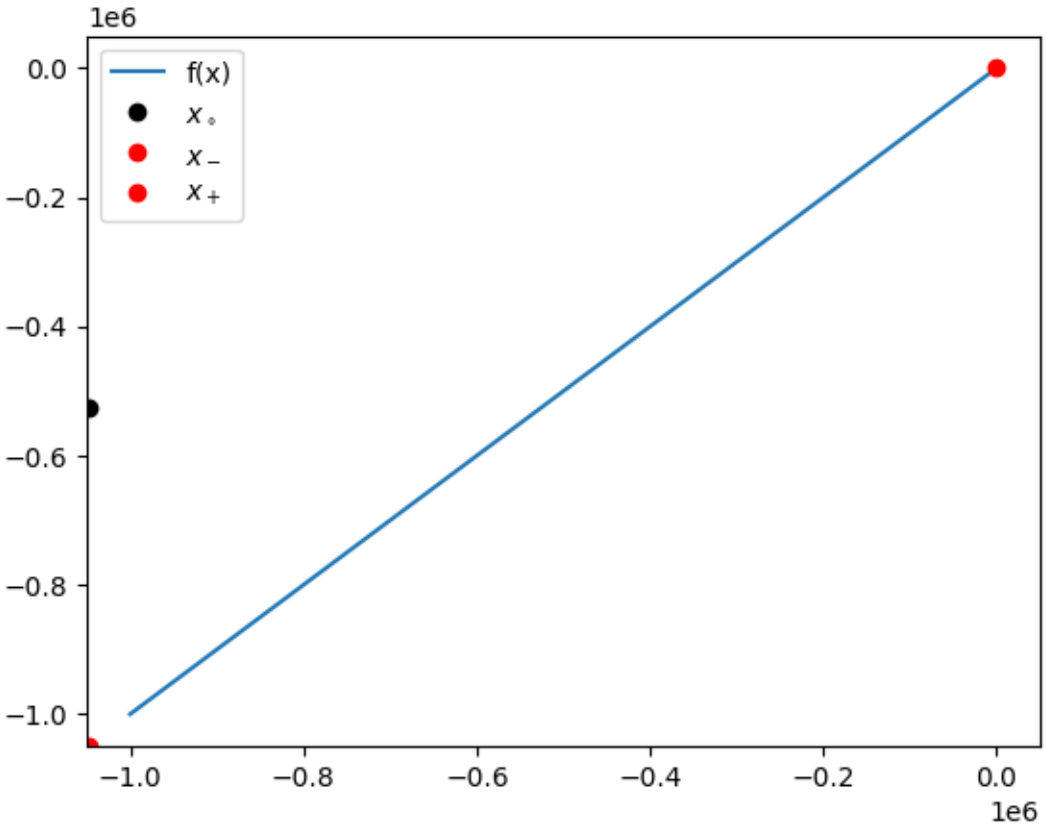

Iterationsverlauf für $f(x) = x^2$ mit x0=2, d0=0.1
Iterierte x_k
Funktionswerte $f(x_k)$
2.0
1.5
1.0
0.5
0.0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
0
20
40

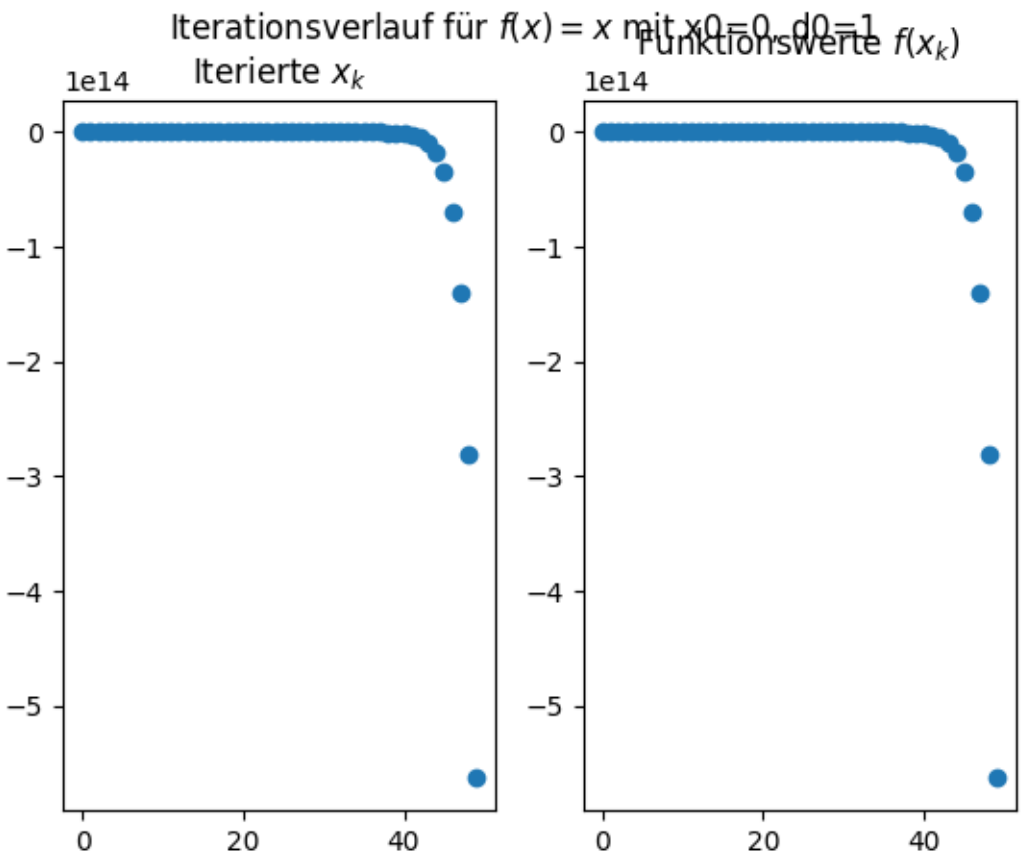

200
150
100
50
0
−15
−10
−5
0
5
10
15
f(x)
$x_\circ$
x_-
x_+

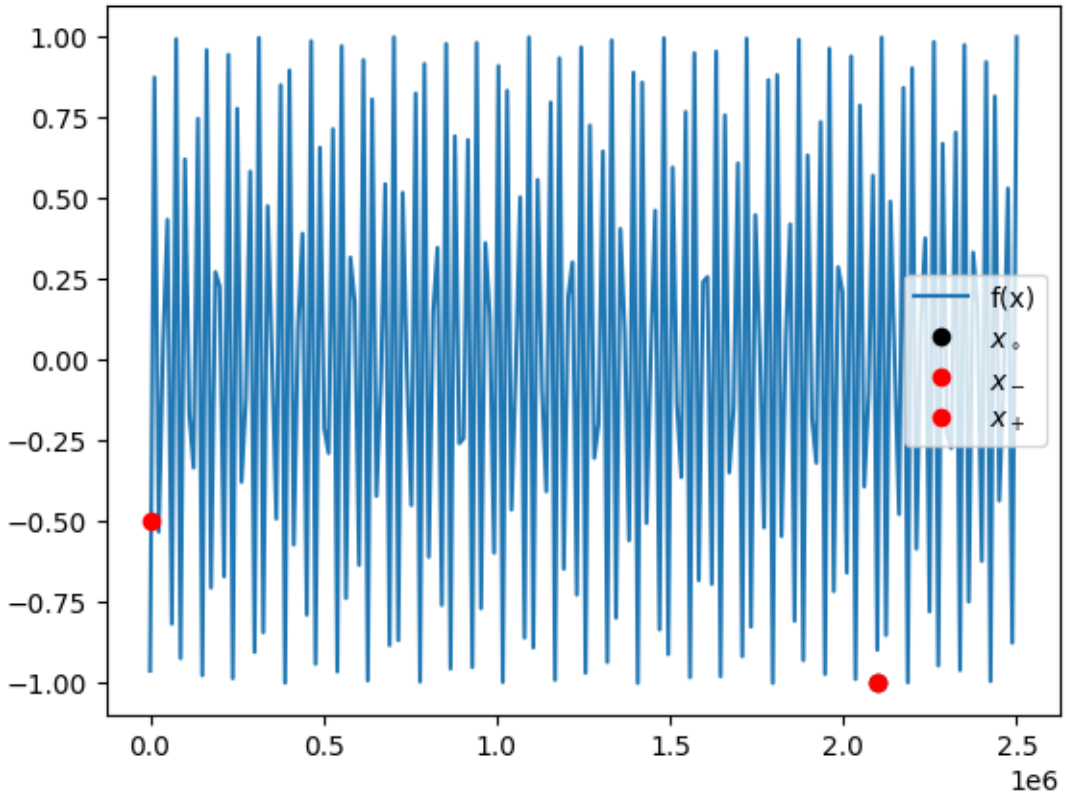

Iterationsverlauf für $f(x) = x^2$ mit x0=-10, d0=1
Iterierte x_k
Funktionswerte $f(x_k)$
0
−2
−4
−6
−8
−10
0
20
40
100
80
60
40
20
0
0
20
40

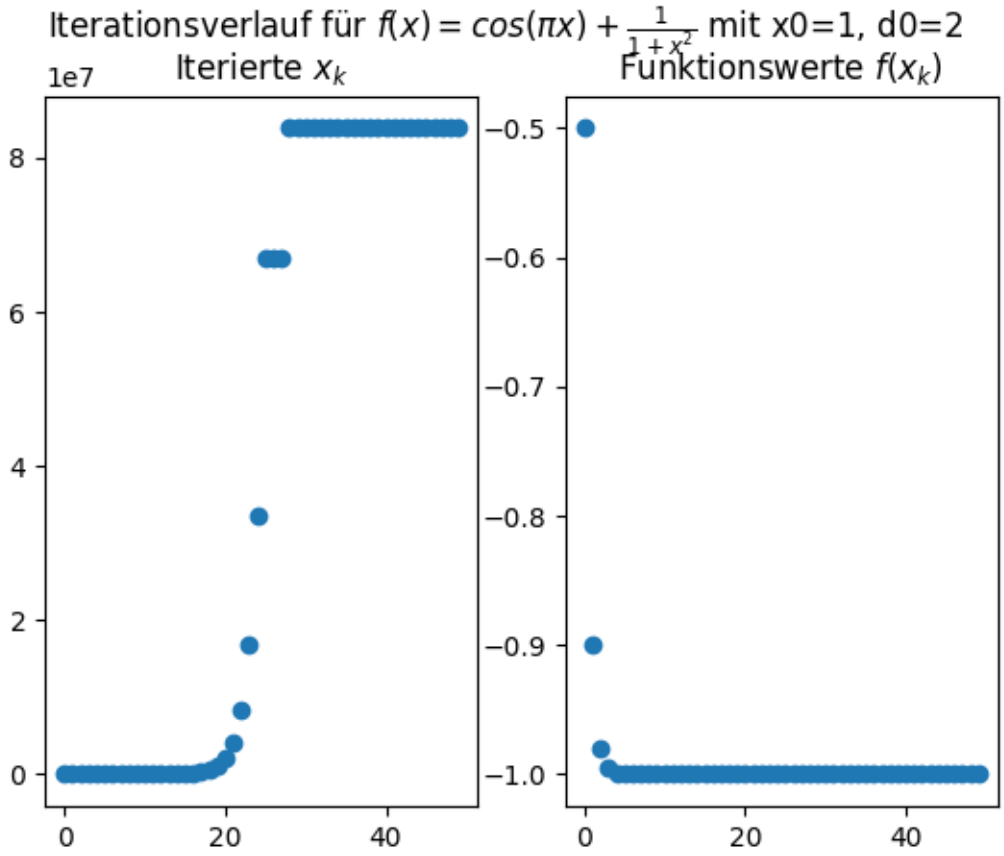

500
400
300
200
100
0
−4
−2
0
2
4
f(x)
$x_\circ$
x_-
x_+


Iterationsverlauf für $f(x) = x^4 - 4x^2$ mit x0=0, d0=1
Iterierte x_k
Funktionswerte $f(x_k)$
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
−3.5
−4.0
0
20
40


1e6
f(x)
$x_\circ$
x_-
x_+
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
1e6


Iterationsverlauf für $f(x) = x$ mit x0=0, d0=1
Iterierte x_k
Funktionswerte $f(x_k)$
1e14
0
−1
−2
−3
−4
−5
0
20
40


1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
f(x)
$x_\circ$
x_-
x_+


Iterationsverlauf für $f(x) = cos(\pi x) + \frac{1}{1+x^2}$ mit x0=1, d0=2
1e7
Iterierte x_k
Funktionswerte $f(x_k)$
8
6
4
2
0
−0.5
−0.6
−0.7
−0.8
−0.9
−1.0
0
20
40
0
20
40

A4\code\utils.py

```python
import matplotlib.pyplot as plt


def plot_iteration_process(log, title='Iterationsverlauf'):
    # Stellt Iterierte und Funktionswerte dar, die Ã¼ber das Dictionary log Ã¼bergeben wurden
    fig, ax = plt.subplots(1, 2)
    ax[0].plot(log['x_list'], 'o')
    ax[0].set_title(r'Iterierte $x_k$')
    ax[1].plot(log['val_list'], 'o')
    ax[1].set_title(r'Funktionswerte $f(x_k)$')
    fig.suptitle(title)

    return fig

#TERMINAL OUTPUT:

#PLOTS:
```