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import numpy as np
import matplotlib.pyplot as plt
from scipy.optimize import curve_fit

def TermProject(StressDrop, TotalNumber, alph, L):
    # Constants
    k = 2
    np.random.seed(42)

    # Generating the Data

    FracX = 200 * np.random.rand(TotalNumber) - 100
    FracY = 200 * np.random.rand(TotalNumber) - 100
    FracZ = 200 * np.random.rand(TotalNumber) - 100

    rndm = (np.random.rand(TotalNumber) + (1 / (100 * 10000))) * 100
    EquivR = ((alph * k) / (StressDrop * np.pi) * (10**6 / rndm)**(3 / 2))**(1 / 3)
    Area = np.pi * EquivR**2 / alph
    Trend = 360 * np.random.rand(TotalNumber)
    Plunge = 90 * np.random.rand(TotalNumber)
    Strike = 360 * np.random.rand(TotalNumber)

    # Preamble
    A = np.vstack((FracX, FracY, FracZ, Area, EquivR, Trend, Plunge, Strike)).T

    # Calling on Stress on Faults code (simulation)

    # Calculating moment magnitude
    M0 = A[:, 3] * A[:, 4] * StressDrop / k
    Mw = 2 / 3 * (np.log10(M0) - 9.1)
    CritFracX, CritFracY, CritFracZ = A[:, 0], A[:, 1], A[:, 2]

    # Initialize containers for plots
    V_list = []
    B_value_list = []
    nbin_list = []
    P_list = []

    # Randomly Generate Spatial Coordinates
    n2 = 0
    for i in range(L):
        RandTemp = 200 * np.random.rand(2, 3) - 100
        SortRand = np.sort(RandTemp, axis=0)

        # Find all faults within the random volume
        n1 = 0
        RandMw = []
        for j in range(len(Mw)):
            if (SortRand[0, 0] < CritFracX[j] < SortRand[1, 0] and
                SortRand[0, 1] < CritFracY[j] < SortRand[1, 1] and
                SortRand[0, 2] < CritFracZ[j] < SortRand[1, 2]):
                n1 += 1
                RandMw.append([CritFracX[j], CritFracY[j], CritFracZ[j], Mw[j]])

        if n1 > 100:
            n2 += 1
            RandMw = np.array(RandMw)
            SortedMw = np.sort(RandMw[:, 3])
            enumerate = np.arange(len(SortedMw), 0, -1)
            P = np.polyfit(SortedMw, np.log10(enumerate), 1)
            V = np.ptp(SortRand[:, 0]) * np.ptp(SortRand[:, 1]) * np.ptp(SortRand[:, 2])
            nbin = len(enumerate)

            # Append to lists for later plotting
            V_list.append(V)
            B_value_list.append(np.abs(P[0]))
            nbin_list.append(nbin)
            P_list.append(P)

    # Plot the Gutenberg-Richter Relationship at intervals
    plt.figure(1)
    plt.semilogy(SortedMw, enumerate, linewidth=4)
    plt.plot(SortedMw, 10**(P[1] + P[0] * SortedMw), linewidth=4)

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plt.title('Synthetic Gutenberg-Richter Relationship')
plt.xlabel('Moment Magnitude')
plt.ylabel('Number of Events')
plt.legend(['Events in the Region', 'Gutenberg-Richter Fit'])
plt.xlim([np.min(SortedMw) - np.ptp(SortedMw) * 1/8, np.max(SortedMw) + np.ptp(SortedMw) * 6/8])
plt.text(SortedMw[-1], 10**(P[1] + P[0] * SortedMw[-1]),
         f'log(N) = {round(P[1], 2)} + {round(P[0], 2)}Mw', fontsize=15)
plt.text(SortedMw[-1], 40, f'n={nbin}', fontsize=15)
plt.text(SortedMw[-1], 20, f'Volume(m^3)={int(V)}', fontsize=15)
plt.gca().tick_params(labelsize=15, width=4)

# Plot B-Value Distribution with Volume
plt.figure(2)
plt.plot(V_list, B_value_list, '.', markersize=15)
sorted_indices = np.argsort(V_list)
sorted_V = np.array(V_list)[sorted_indices]
sorted_B_value = np.array(B_value_list)[sorted_indices]
window_size = 50
moving_average = np.convolve(sorted_B_value, np.ones(window_size)/window_size, mode='valid')
plt.plot(sorted_V[window_size-1:], moving_average, 'm', linewidth=1.2)
plt.title('Synthetic B-Value Distribution with Volume')
plt.xlabel('Volume (m^3)')
plt.ylabel('B-Value')
plt.legend(['B-Value for each region', 'Moving Average (n=50)'])
plt.gca().tick_params(labelsize=15, width=4)

# Plot Earthquake Activity
plt.figure(3)
plt.plot(nbin_list, [P[1] for P in P_list], '.', markersize=15)
def model(x, b0, b1, b2):
    return b0 + b1 * np.log10(b2 * x)
beta, _ = curve_fit(model, nbin_list, 3 + np.array([P[1] for P in P_list]))
plt.plot(np.sort(nbin_list), -3 + beta[0] + beta[1] * np.log10(beta[2] * np.sort(nbin_list)), linewidth=4)
plt.title('Synthetic Earthquake Activity')
plt.xlabel('Number of Events in the Region')
plt.ylabel('A-Value')
plt.text(250, -.25, f'A = {round(-3 + beta[0], 1)} + {round(beta[1], 1)} log({round(abs(beta[2]), 1)}N)', fontsize=15)
plt.gca().tick_params(labelsize=15, width=4)

# Plot Number of Events vs. Volume
plt.figure(4)
plt.plot(V_list, nbin_list, '.', markersize=20)
VolFit = np.polyfit(V_list, nbin_list, 1)
V_list = np.array(V_list)
plt.plot(V_list, VolFit[0] * V_list + VolFit[1], linewidth=4)
plt.title('Synthetic Volume vs Number of Events in Each Region')
plt.xlabel('Volume (m^3)')
plt.ylabel('Number of Events in Each Region')
plt.gca().tick_params(labelsize=15, width=4)

plt.show()

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TermProject (StressDrop=10, TotalNumber=1000, alph=0.7, L=5000)