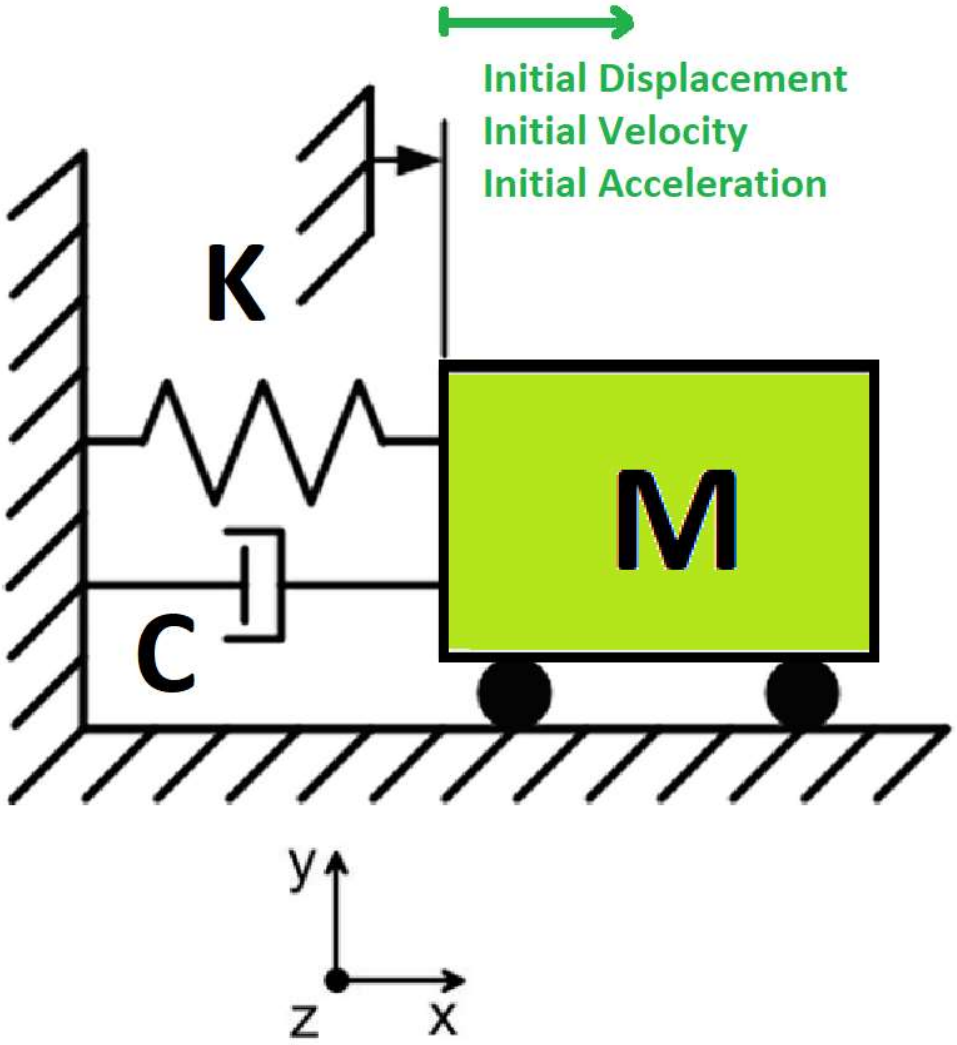
>> IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL <<

# PERFORMANCE-CONSTRAINED OPTIMIZATION OF AN SDOF STRUCTURAL SYSTEM USING OPENSEESPY AND NONLINEAR DYNAMIC ANALYSIS

**OPTIMIZATION ALGORITHM: SLSQP (Sequential Least Squares Programming)**

WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)


Initial Displacement
Initial Velocity
Initial Acceleration
K
M
C
y
z
x

Spyder (Python 3.12)

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```
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#                                          FIND OPTIMAL SPRING AREA
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#                              THIS PROGRAM WRITTEN BY SALAR DELAVAR GHASHGHAEI (QASHQAI)
#                                   EMAIL: salar.d.ghashghaei@gmail.com
#############################################################################################
"""
Performance-Constrained Optimization of an SDOF Structural System Using OpenSeesPy and Nonlinear
-------------------------------------------------------------------------------

Performs free-vibration analysis of a Single Degree of Freedom (SDOF)
 structure using OpenSeesPy, comparing elastic and inelastic spring behavior.
 Key features include:

1. The developed code integrates OpenSeesPy to model and analyze the free-vibration
 response of a single-degree-of-freedom (SDOF) structural system, considering both
 elastic and inelastic spring characteristics.
2. The primary design variable is the cross-sectional area of the structural element,
 a parameter that governs stiffness, strength, and dynamic response characteristics.
3. The core analysis routine, `FREE_VIBRATION_SDOF`, generates time histories for
 displacement, velocity, acceleration, base shear, tangent stiffness, fundamental
 period, and damping ratio.
4. From these results, the routine extracts extreme values (minimum and maximum)
 of each parameter to facilitate performance verification against engineering design criteria.
5. The optimization objective is to minimize the cross-sectional area, thereby reducing
 material consumption while ensuring compliance with performance requirements.
6. Performance constraints (e.g., `disp_max ≤ 0.05 m`, `0.01 ≤ damping_ratio ≤ 0.10`)
 are defined explicitly and reflect serviceability, stability, and damping considerations.
7. A constraint generation function translates these design limits into nonlinear inequality
 constraints compatible with the `scipy.optimize` framework.
```

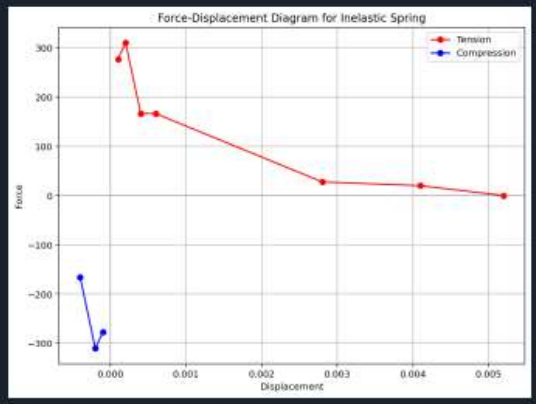


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Console 1/A

```
Positive directional derivative for linesearch    (Exit mode 8)
            Current function value: 0.09999999999999327
            Iterations: 21
            Function evaluations: 160
            Gradient evaluations: 17
Optimal Area: 0.09999999999999327

Total time (s): 198.9219
```

IPython Console | History

Inline | Conda: anaconda3 (Python 3.12.7) | LSP: Python | Line 4, Col 119 | UTF-8 | CRLF | RW | Mem 32%

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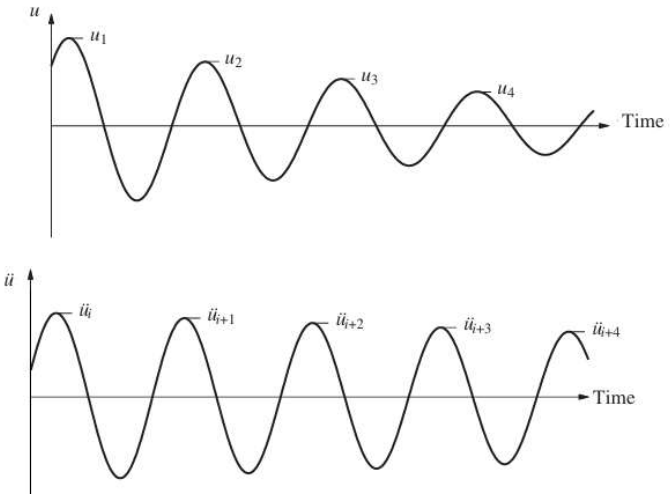
# VISCOUSLY DAMPED FREE VIBRATION

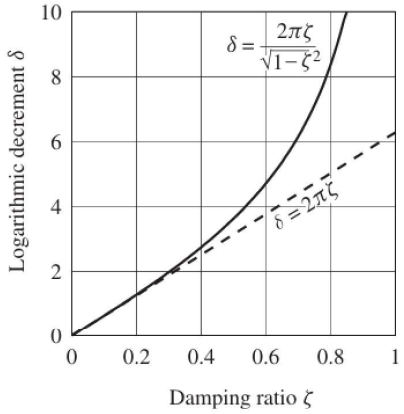
$$m\ddot{u} + c\dot{u} + ku = 0$$

$$\ddot{u} + 2\zeta\omega_n\dot{u} + \omega_n^2 u = 0$$

$$\omega_n = \sqrt{k/m} \qquad \zeta = \frac{c}{2m\omega_n} = \frac{c}{c_{cr}} \qquad \omega_D = \omega_n\sqrt{1-\zeta^2}$$

$$u(t) = e^{-\zeta\omega_n t}\left[u(0)\cos\omega_D t + \frac{\dot{u}(0) + \zeta\omega_n u(0)}{\omega_D}\sin\omega_D t\right]$$




## Decay of Motion

$$\delta = \ln\frac{u_i}{u_{i+1}} = 2\pi\zeta$$ (APPROXIMATE RELATION)

$$\delta = \ln\frac{u_i}{u_{i+1}} = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}}$$ (EXACT RELATION)

**EXACT AND APPROXIMATE RELATIONS BETWEEN LOGARITHMIC DECREMENT AND DAMPING RATIO**