C1 Comparisons

March 3, 2025

[1]:
```
%matplotlib widget
import pandas as pd
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
kole_er_sheets = pd.read_excel("Kole/Kole_ER_BigData.xlsx", engine="calamine",␣
↪sheet_name=None)

for sheet_name, kole_er_df in kole_er_sheets.items():
    fig = plt.figure(f"Kole: {sheet_name}")
    ax = fig.add_subplot(111, projection='3d')
    ax.scatter(kole_er_df['X'], kole_er_df['Y'], kole_er_df['Z'], c='blue',␣
↪marker='o')
    ax.set_xlabel('X Coordinate')
    ax.set_ylabel('Y Coordinate')
    ax.set_zlabel('Z Coordinate')
    plt.show()
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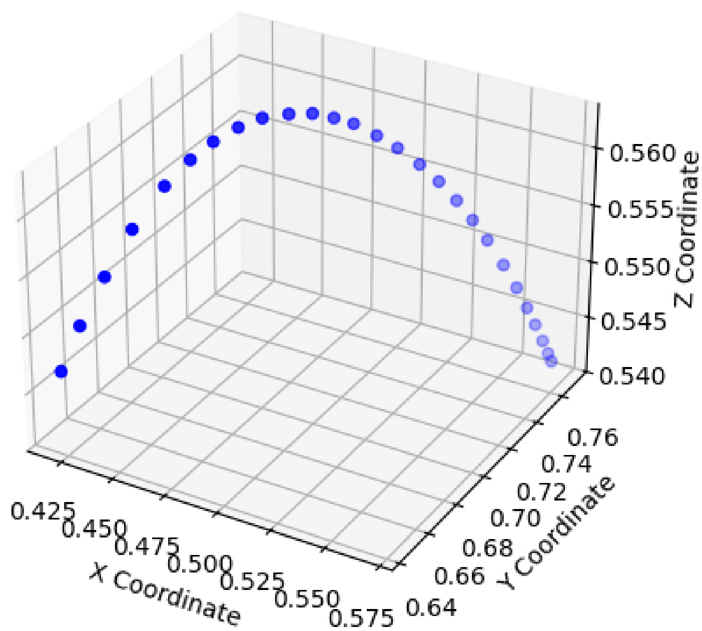
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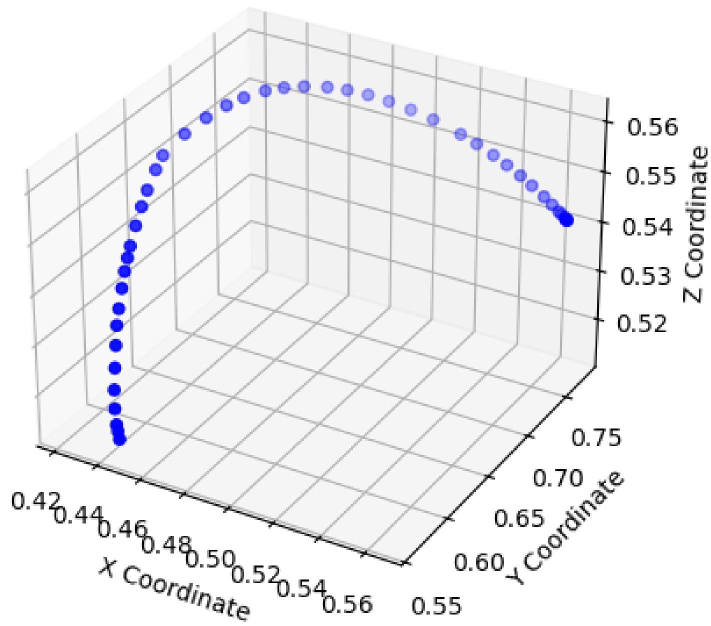
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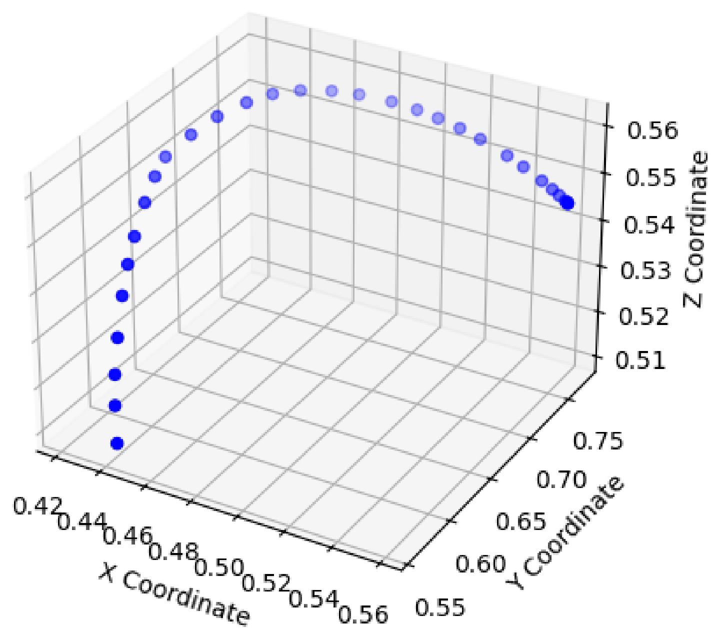

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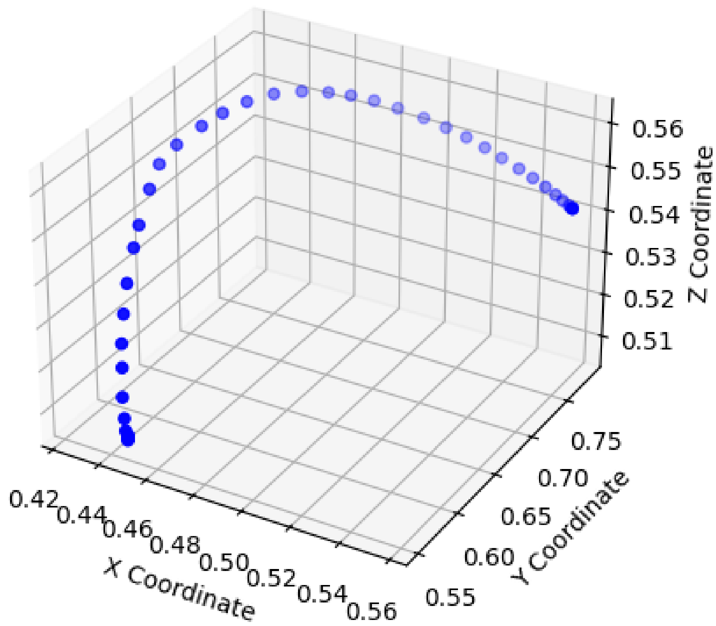

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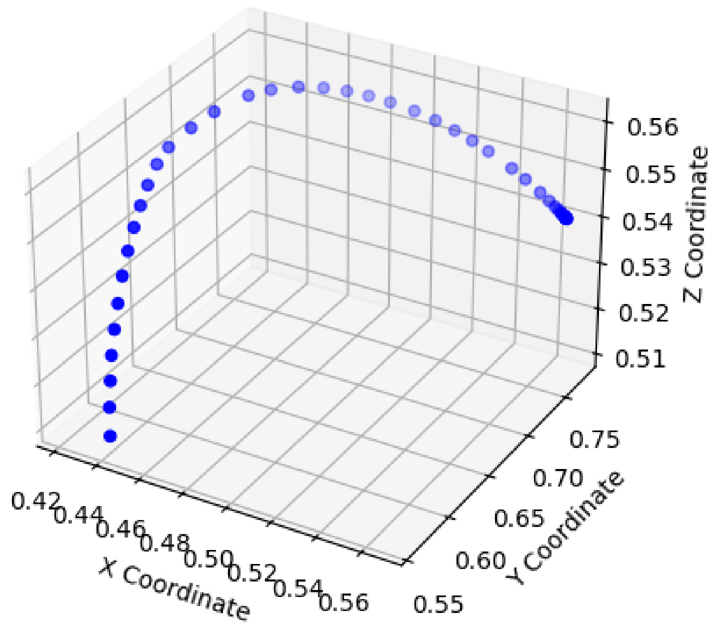
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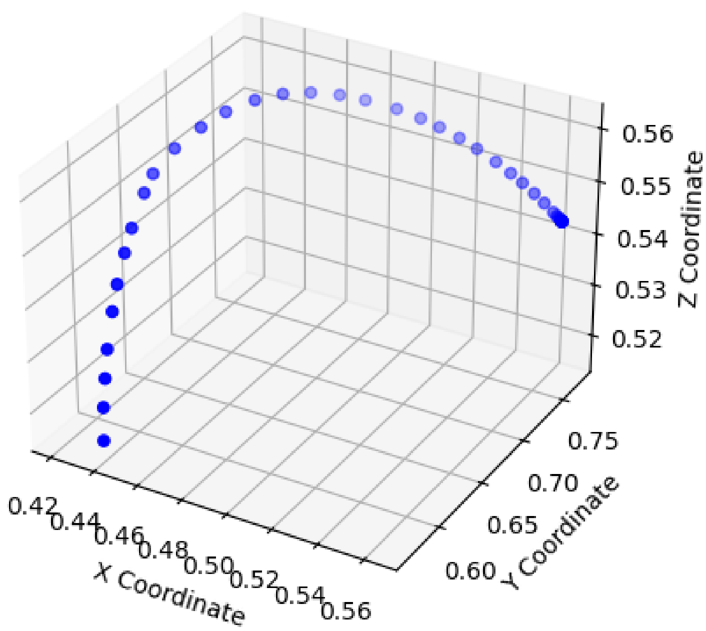
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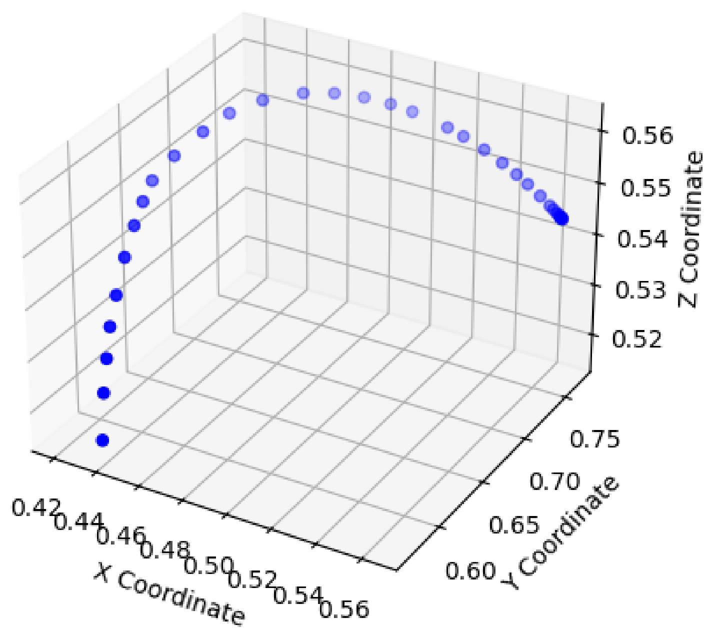
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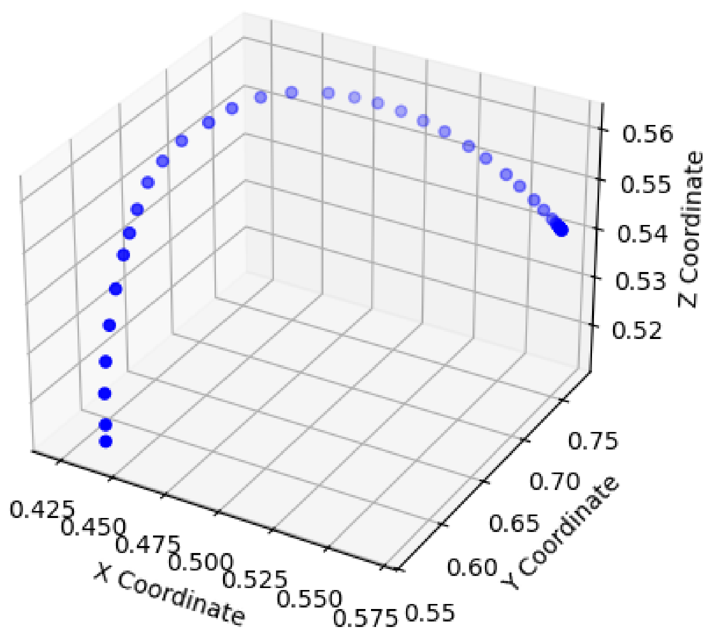
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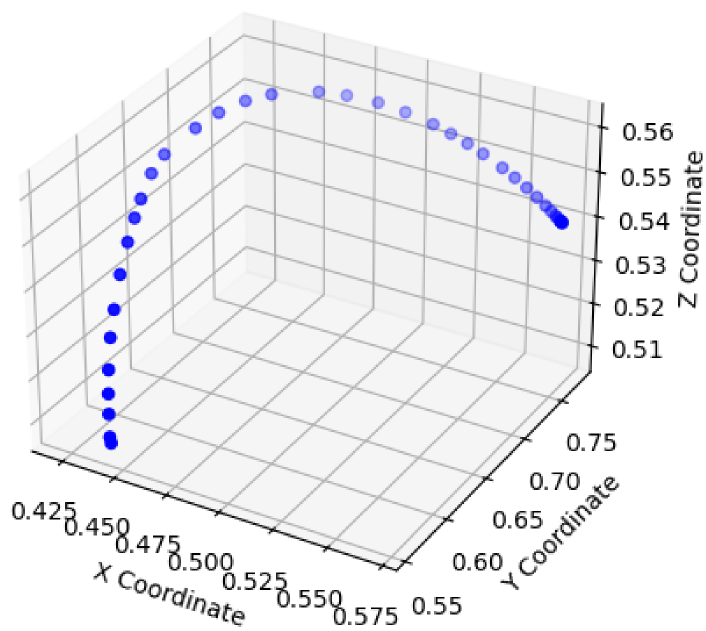
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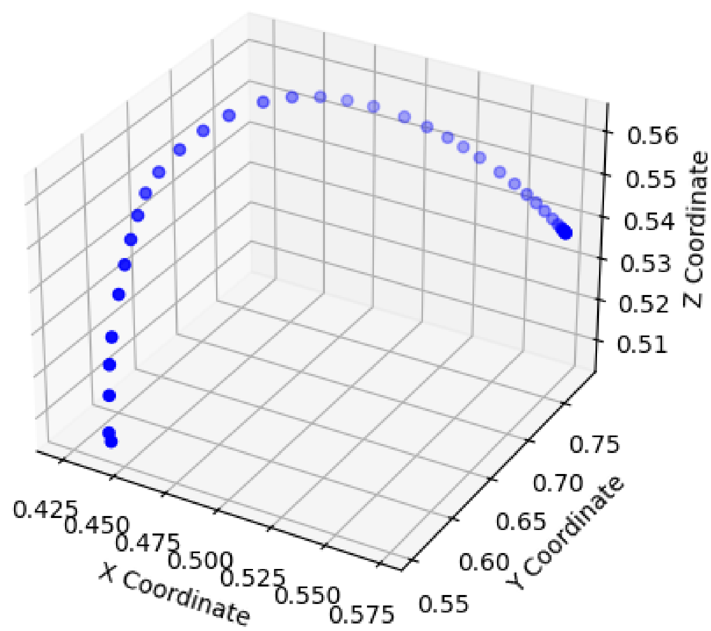
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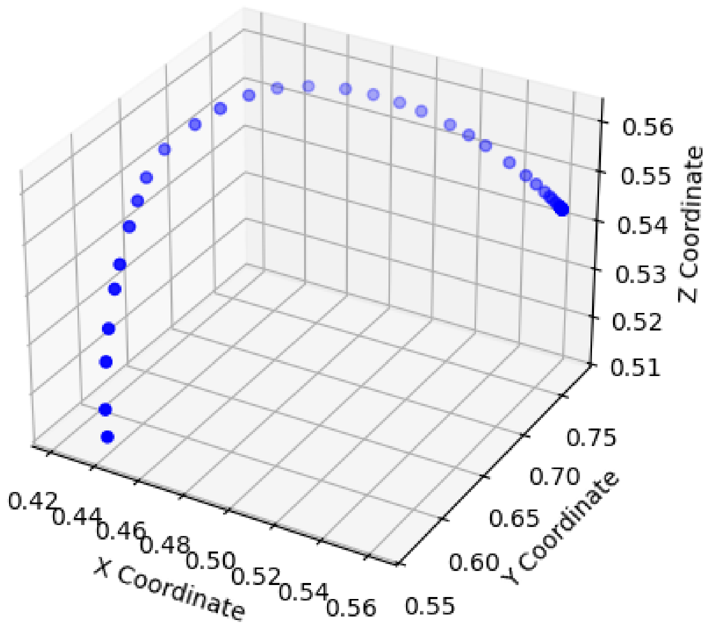
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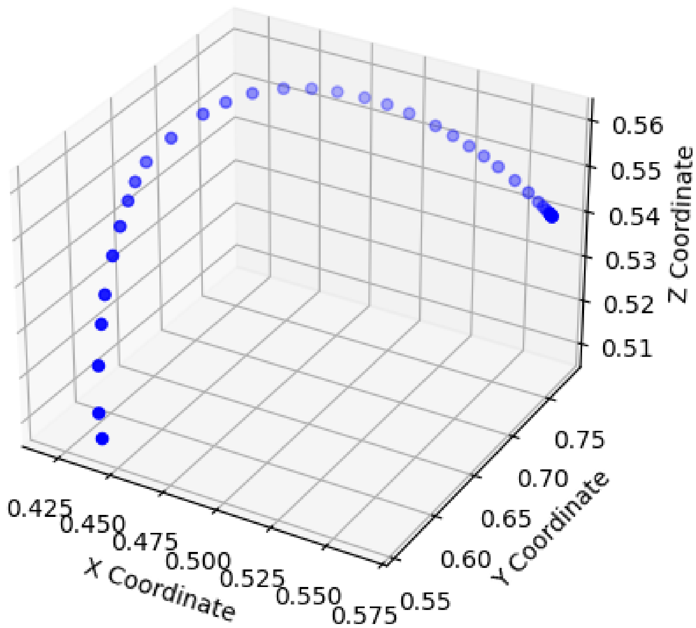

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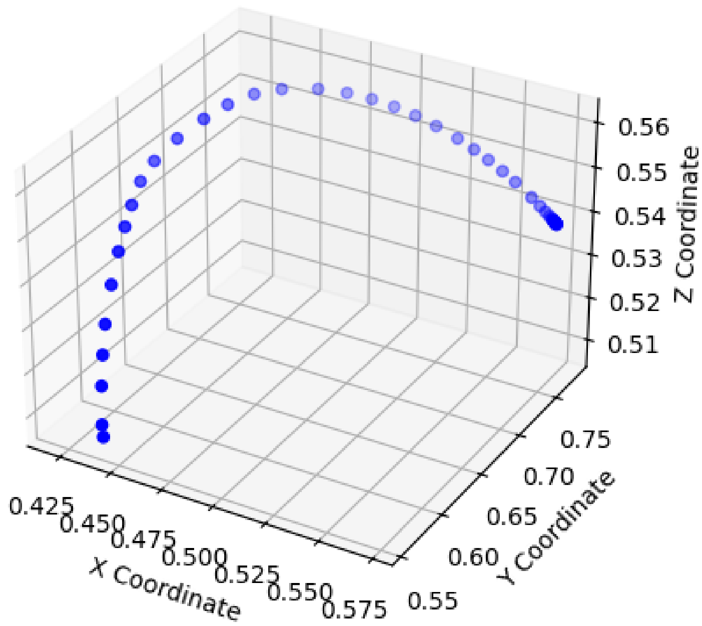
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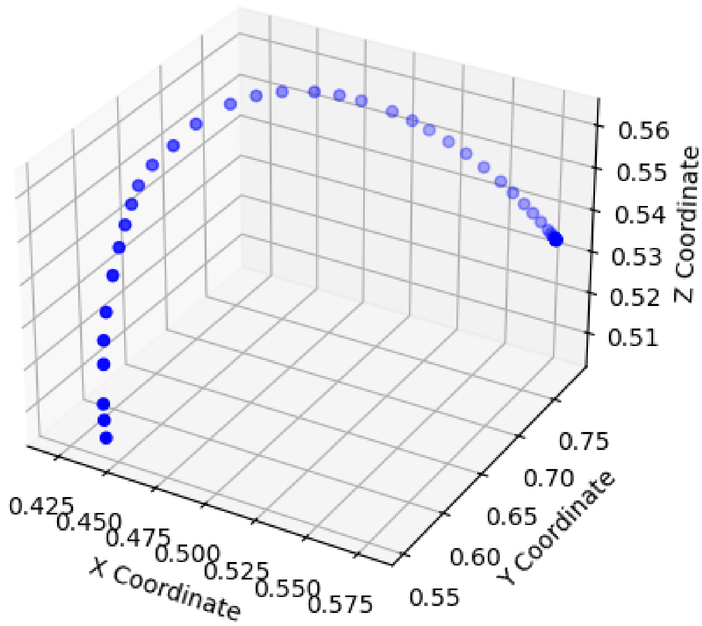
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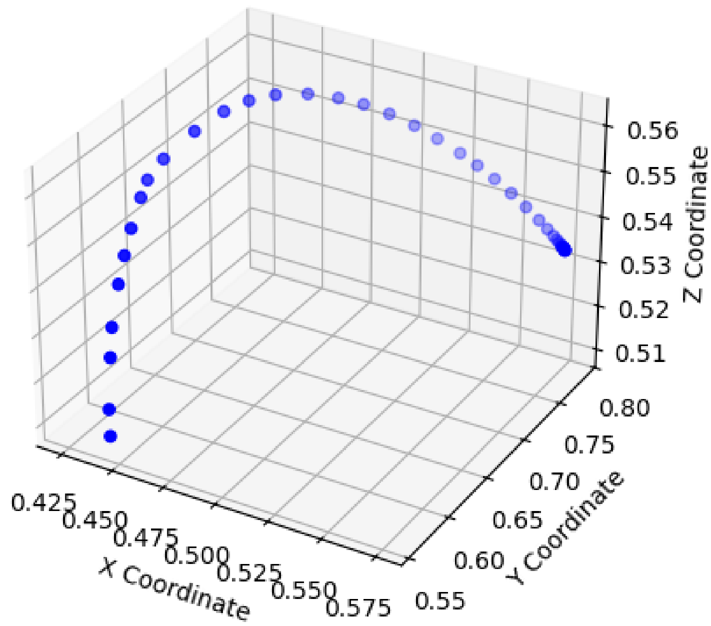
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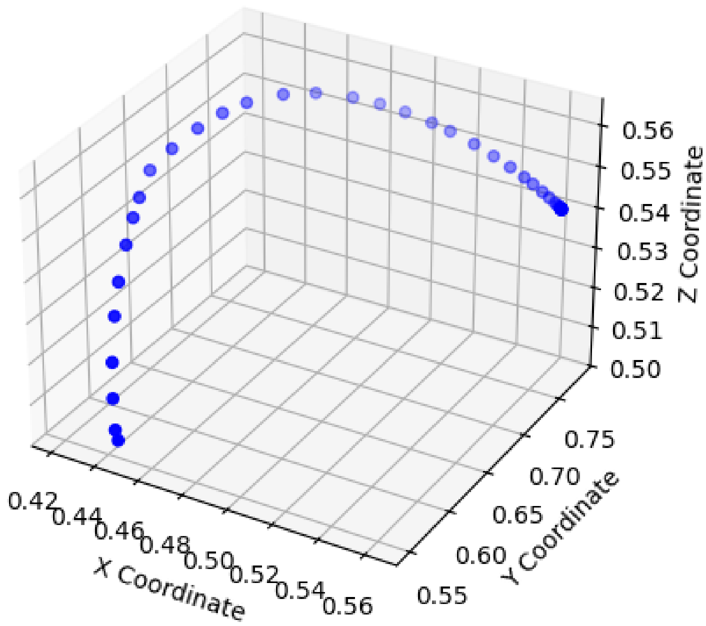

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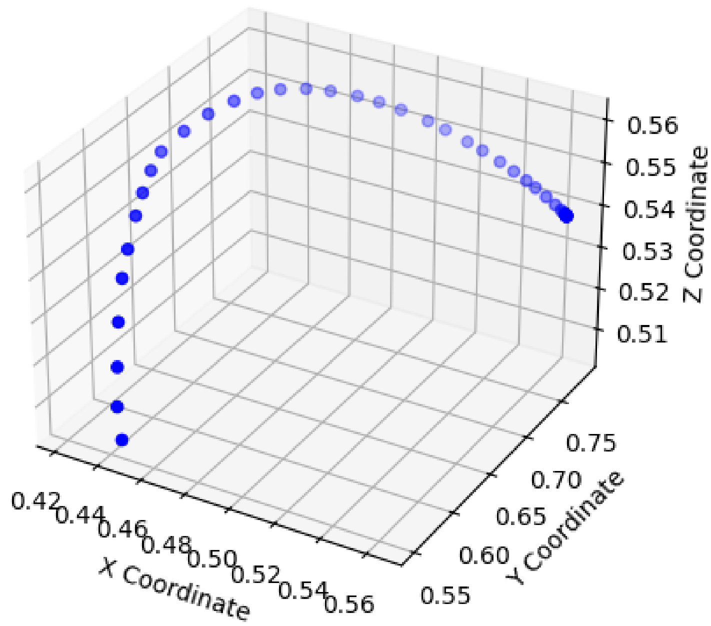
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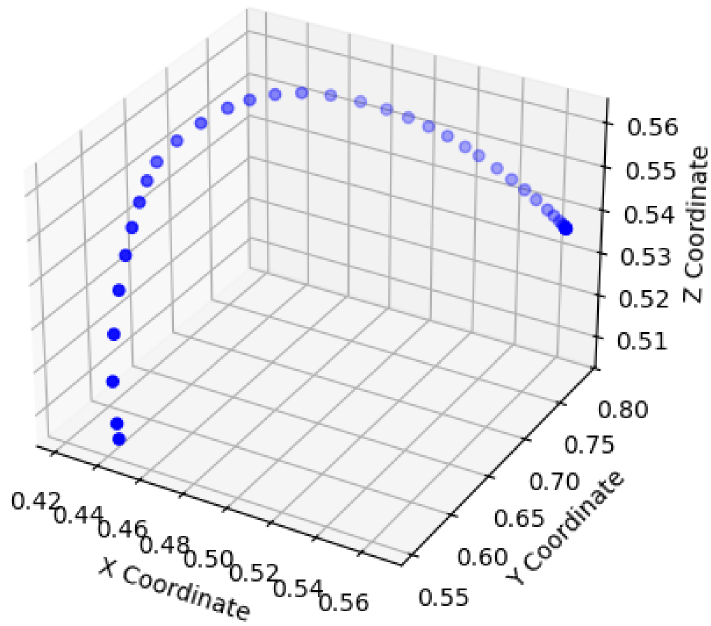

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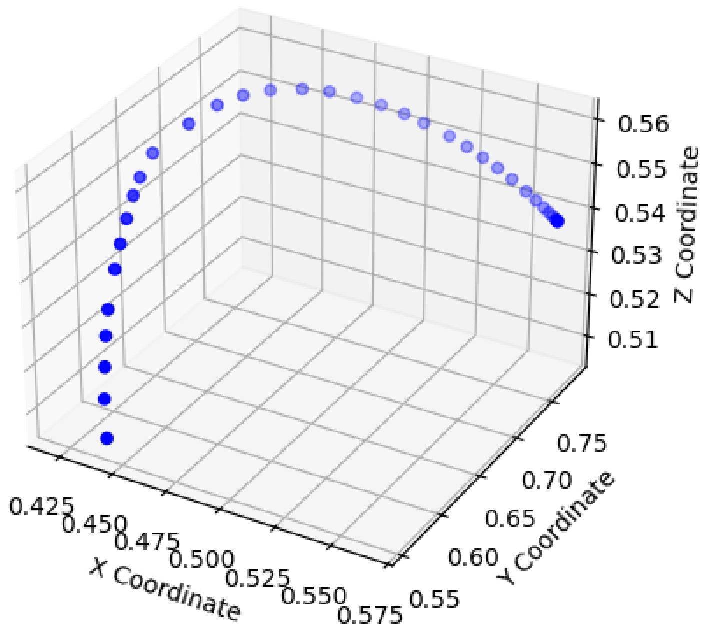

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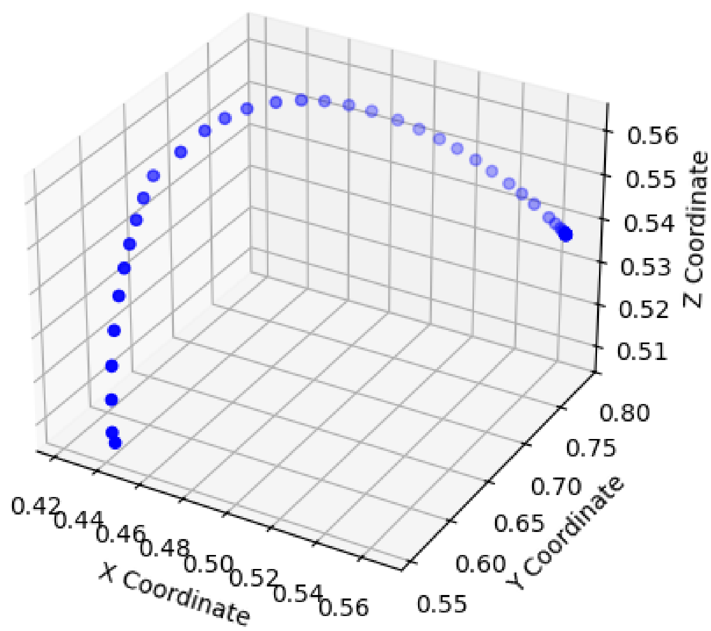


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/tmp/ipykernel_210142/1548511636.py:8: RuntimeWarning: More than 20 figures have
been opened. Figures created through the pyplot interface
(`matplotlib.pyplot.figure`) are retained until explicitly closed and may
consume too much memory. (To control this warning, see the rcParam
`figure.max_open_warning`). Consider using `matplotlib.pyplot.close()`.
  fig = plt.figure(f"Kole: {sheet_name}")
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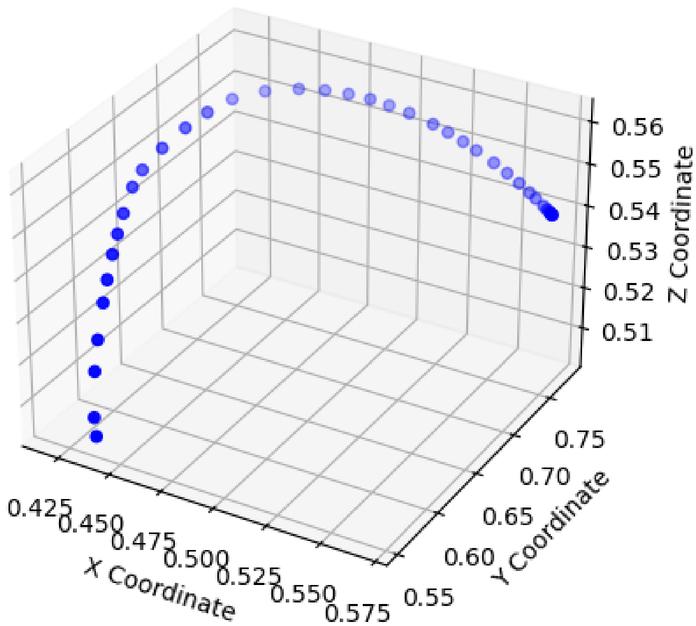
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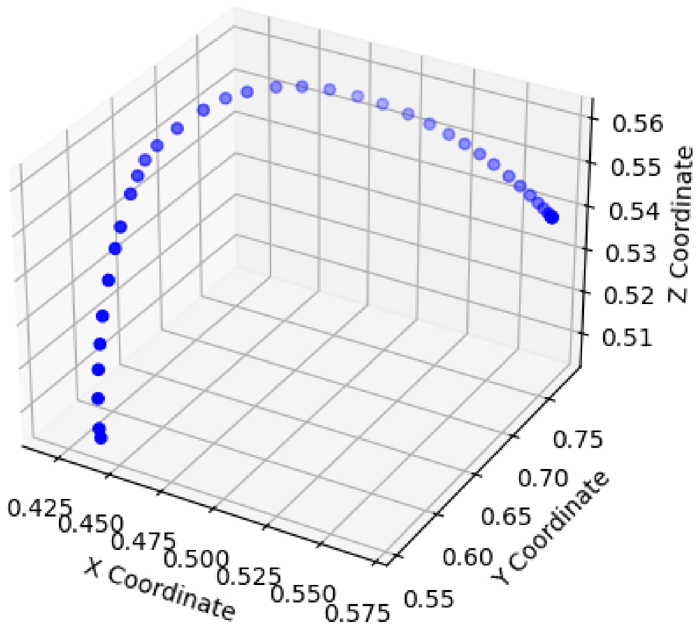
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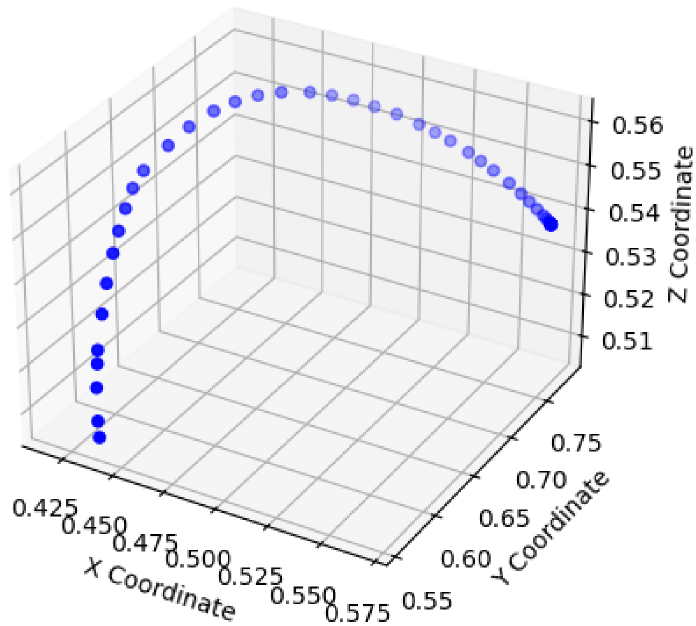
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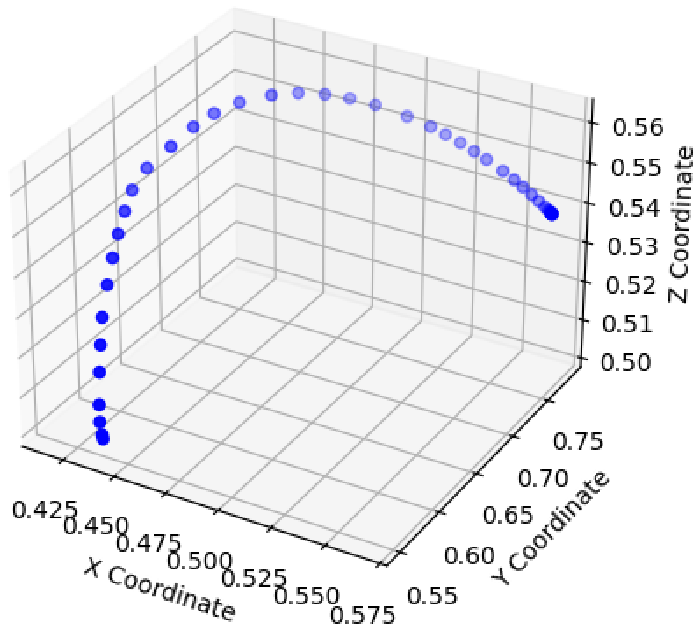
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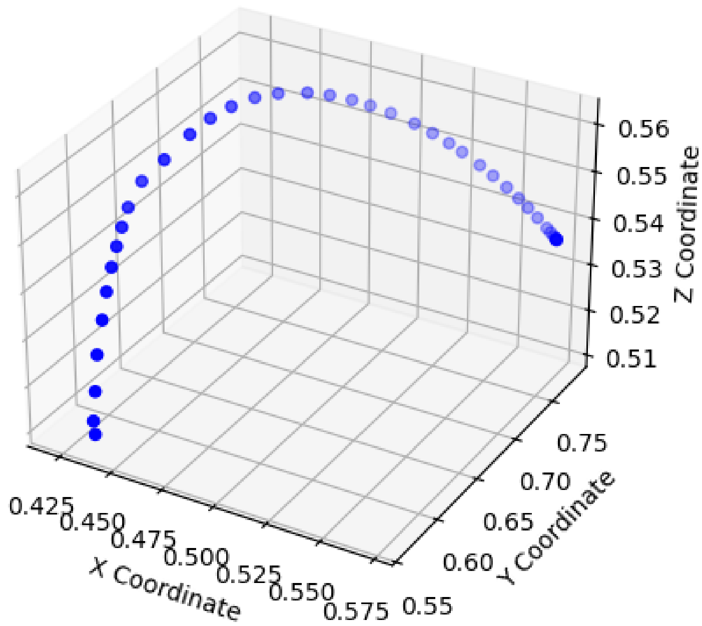
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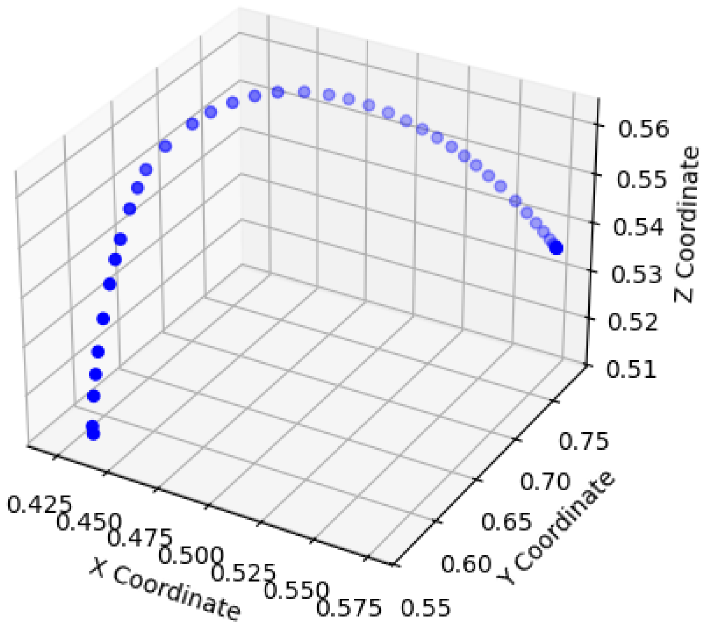
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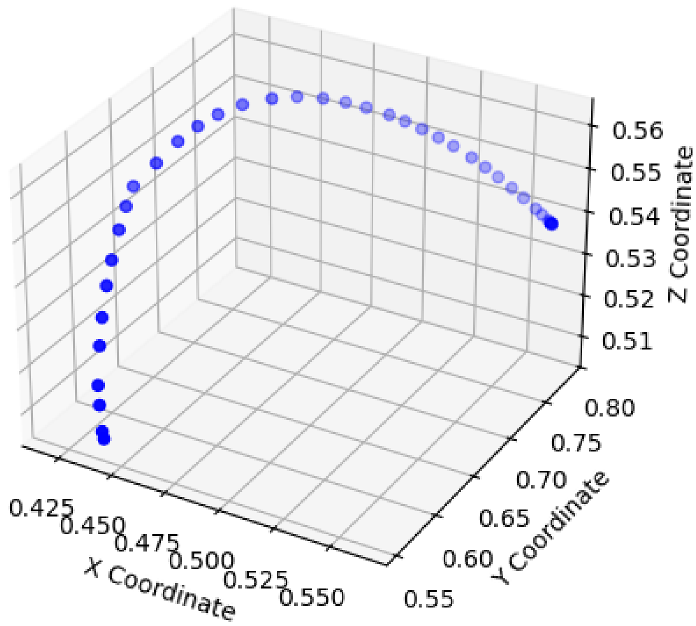

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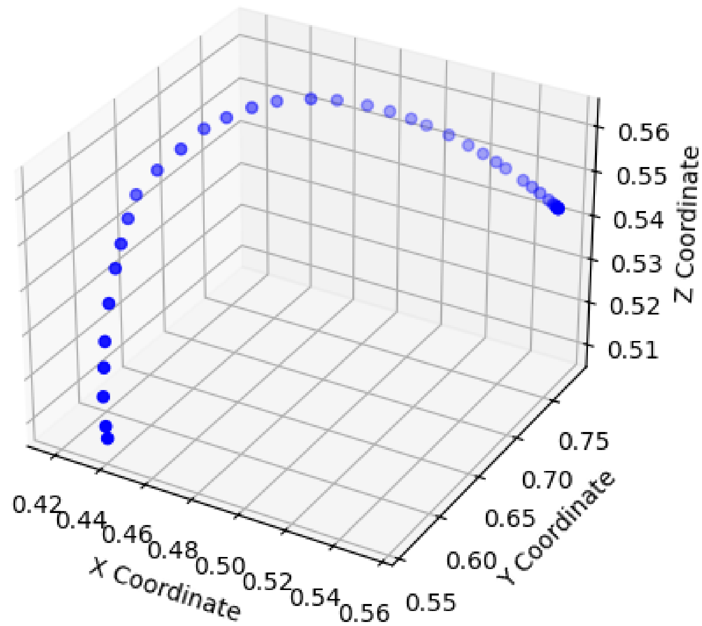
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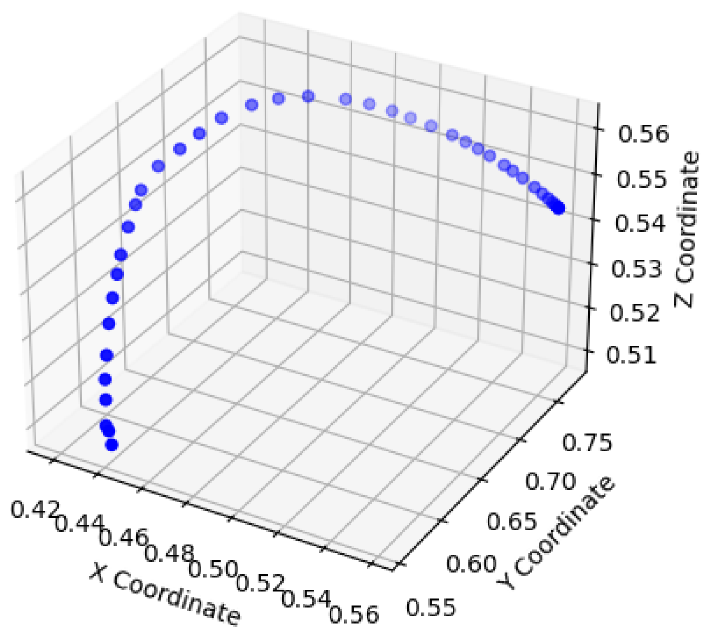
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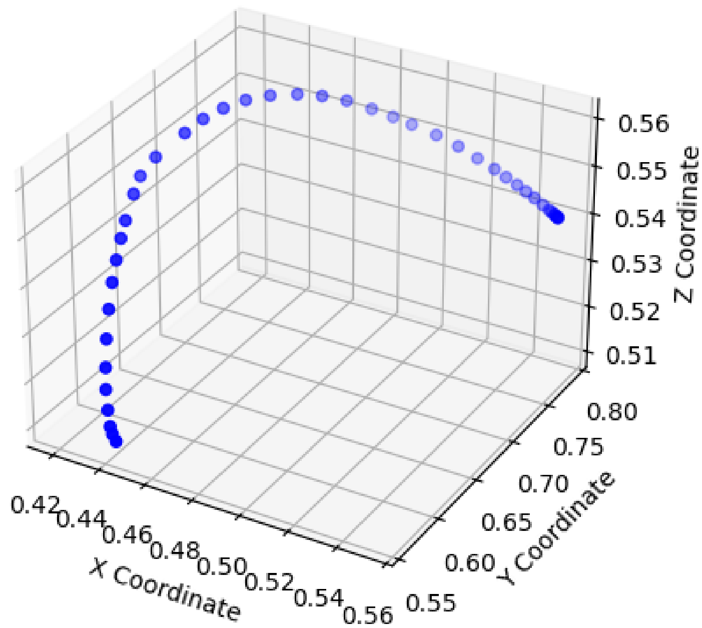

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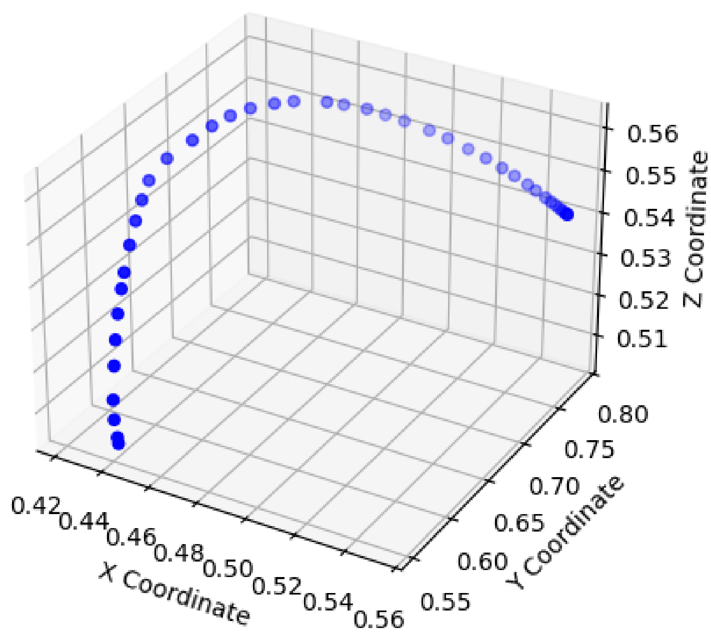
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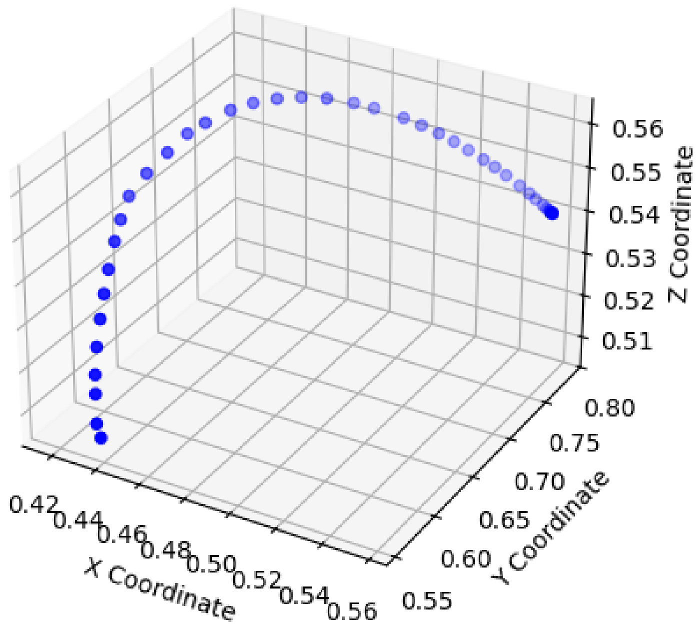
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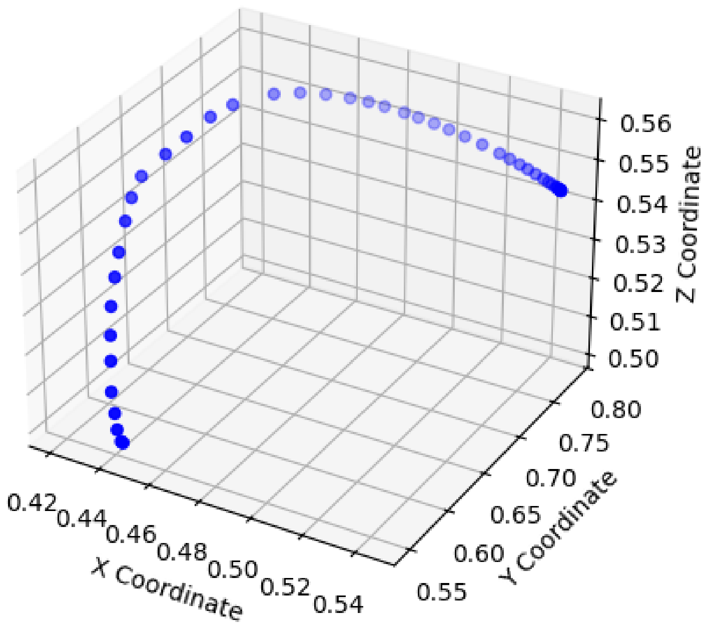
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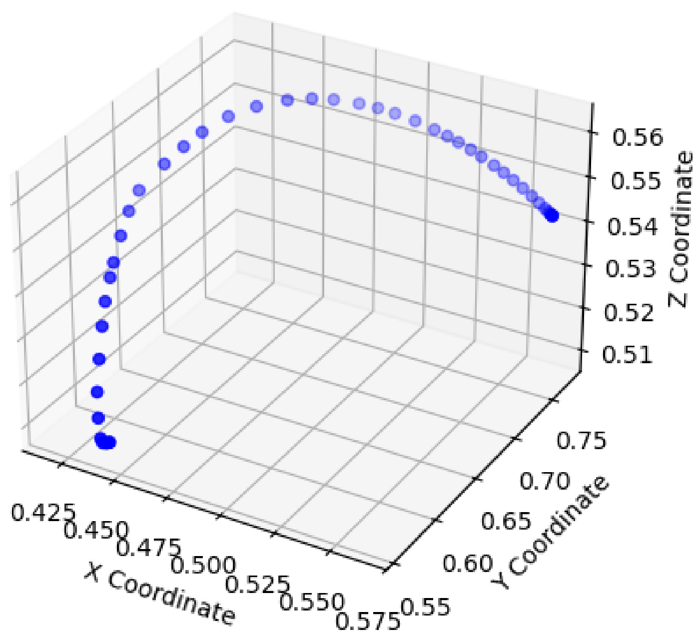

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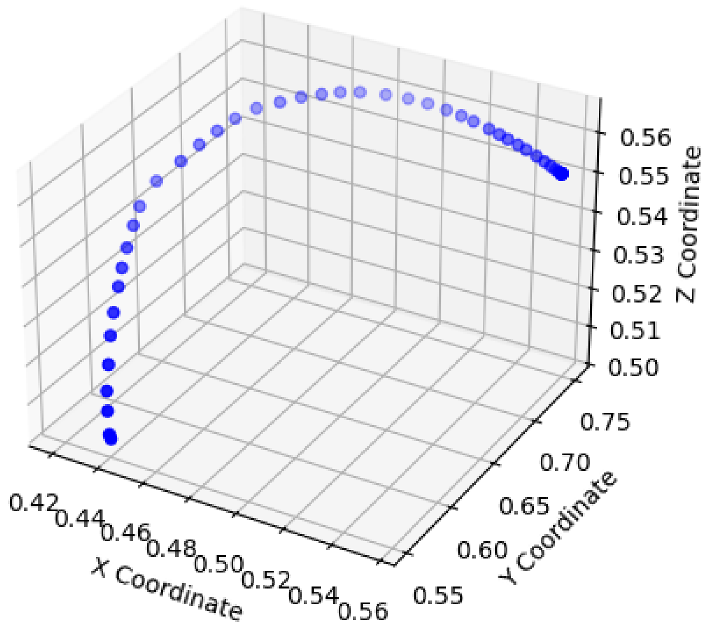

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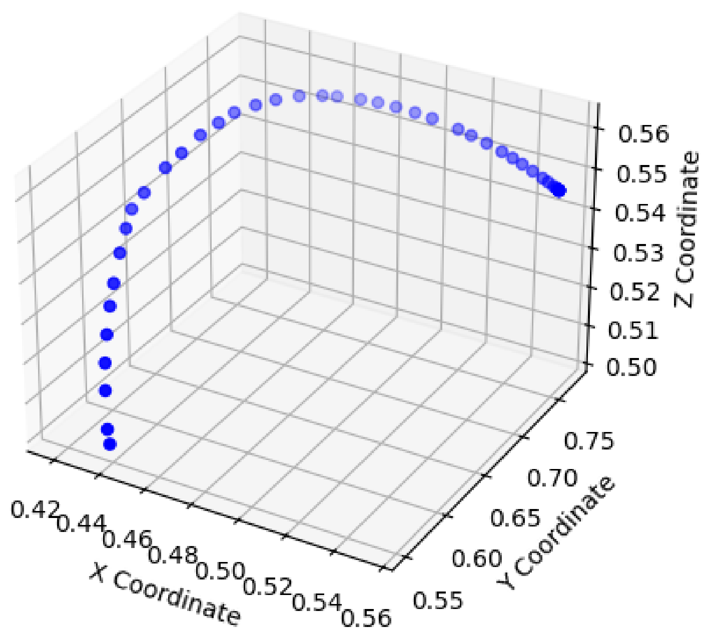

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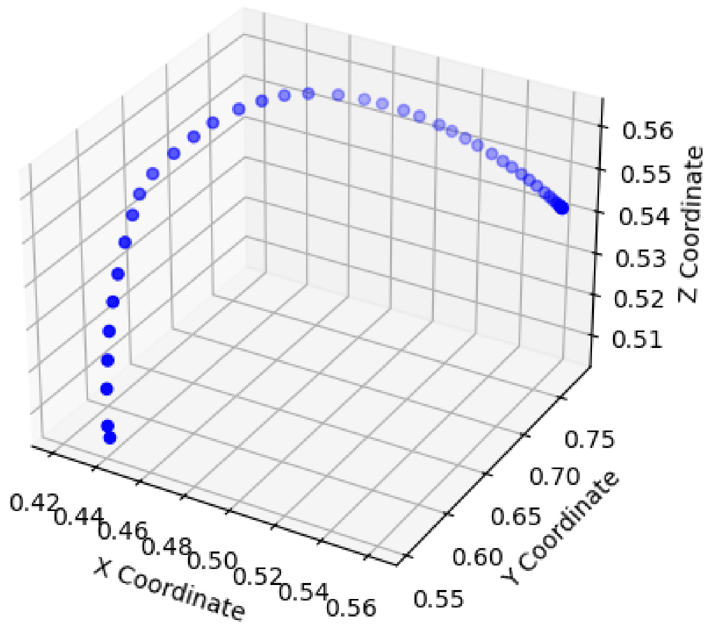
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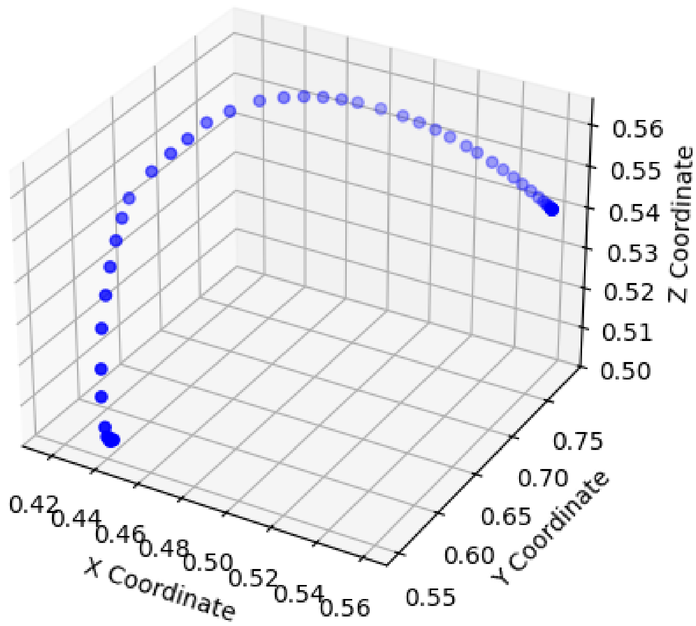
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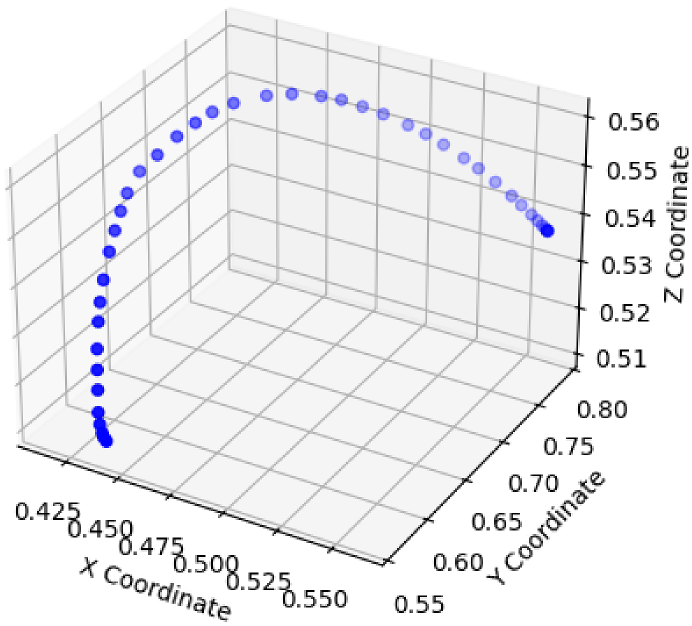
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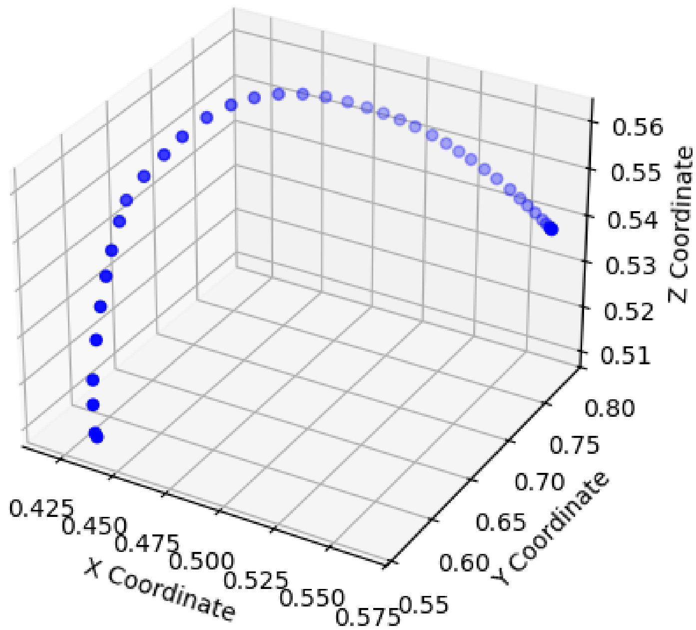

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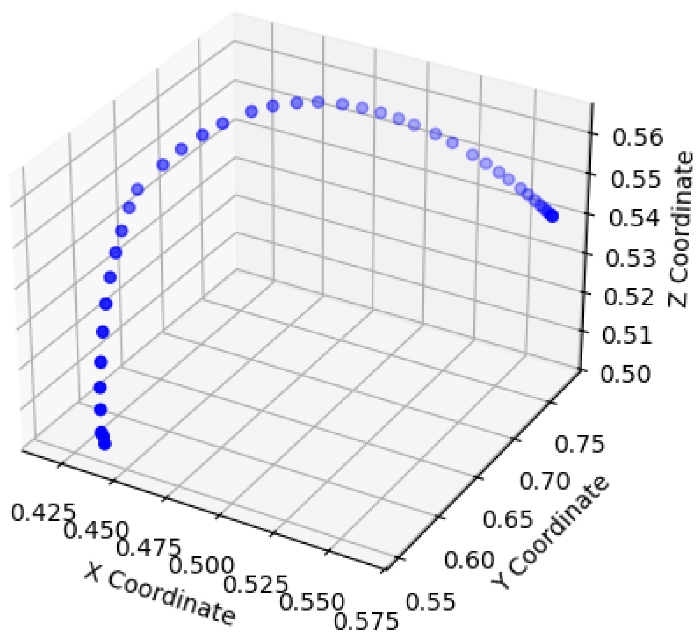
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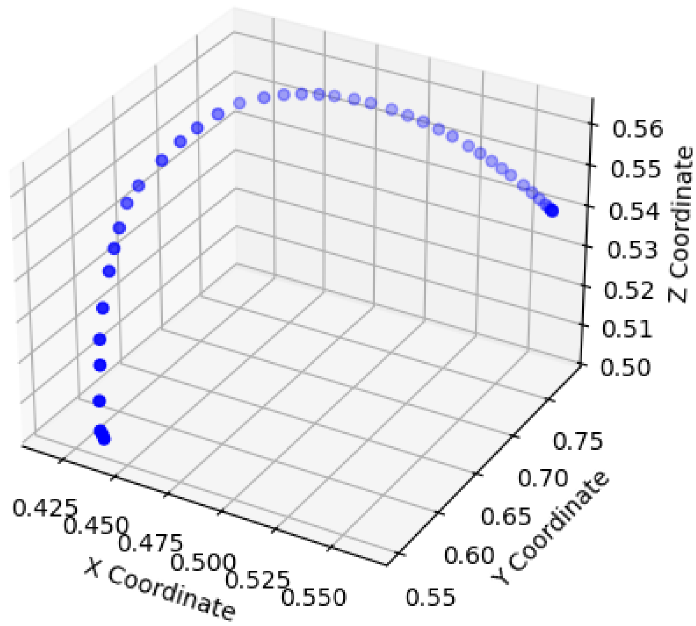
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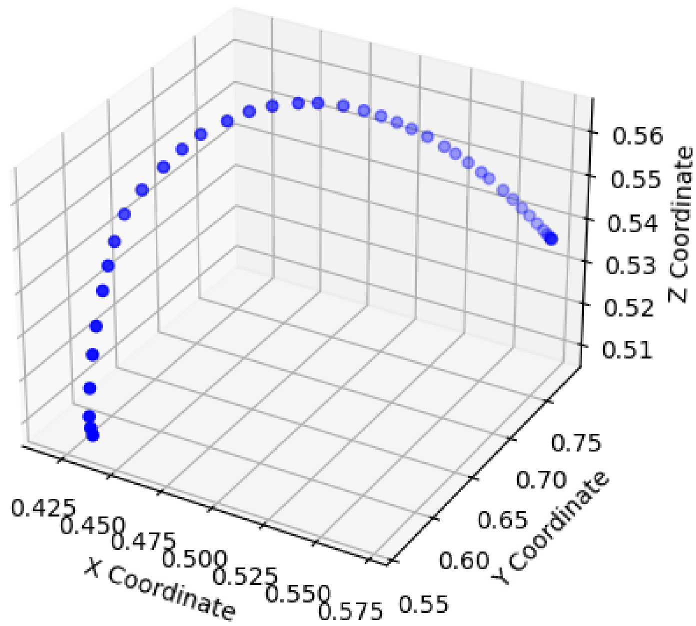
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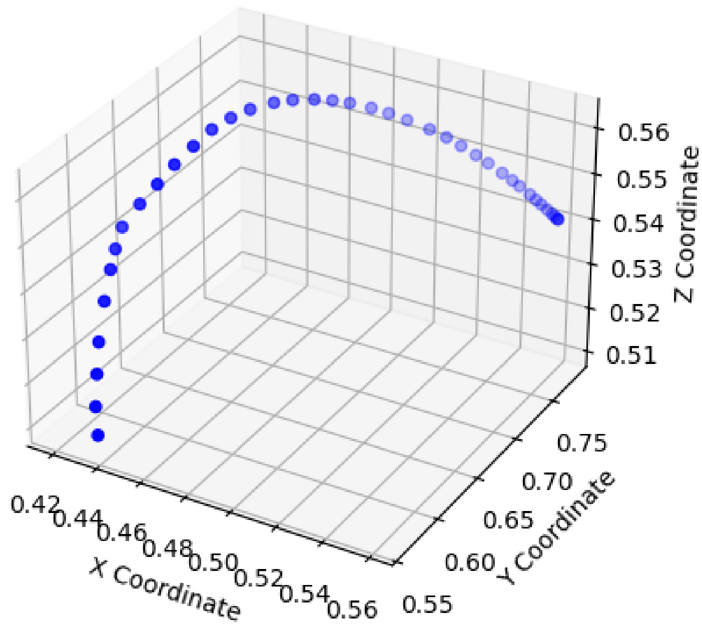
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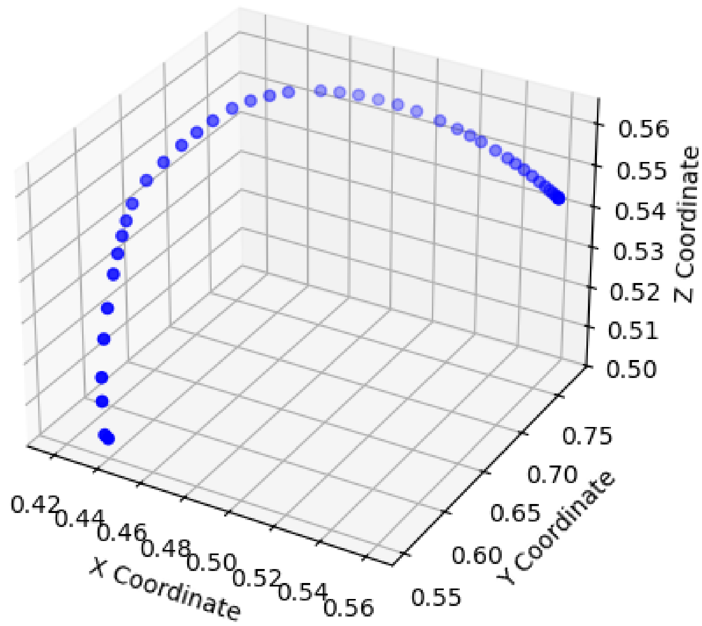
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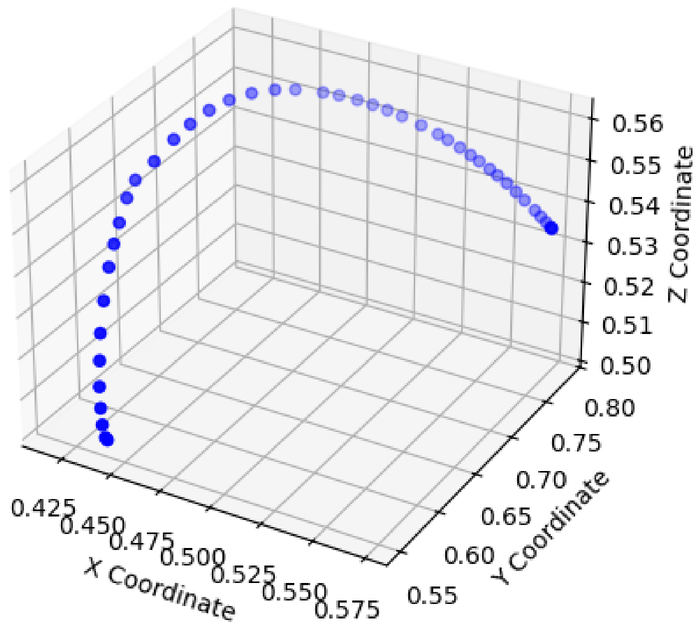

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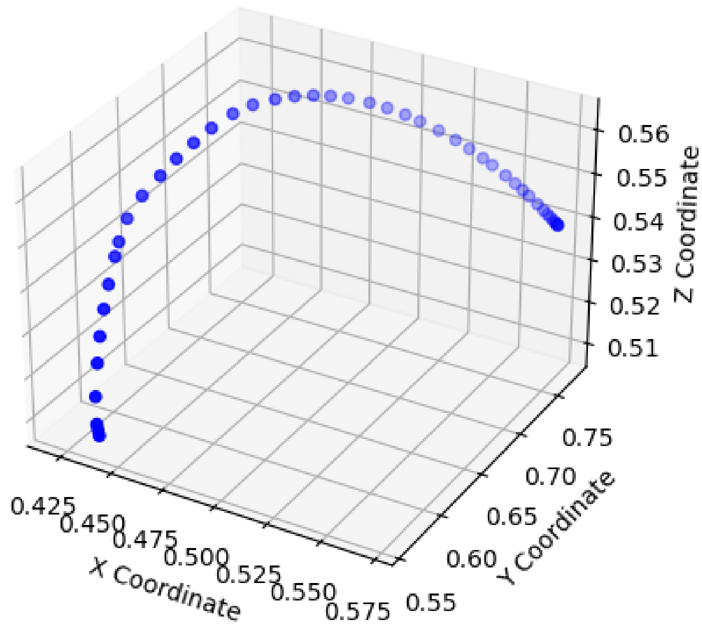
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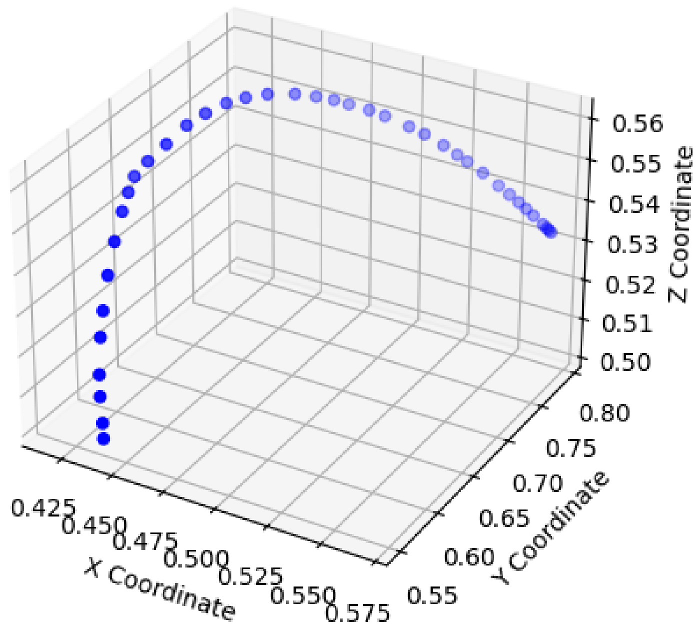
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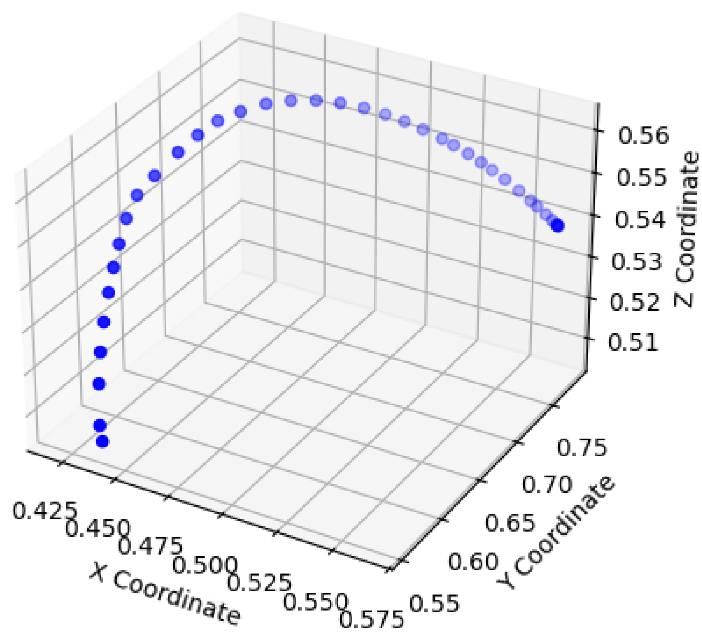
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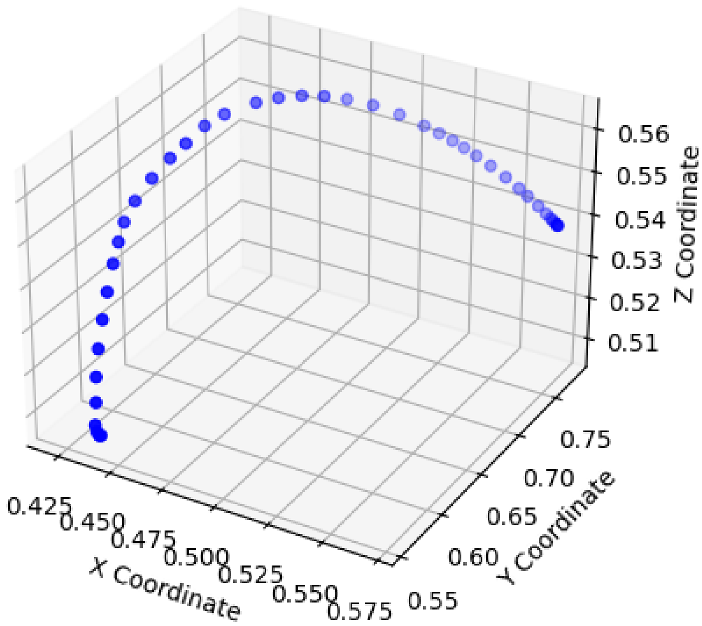
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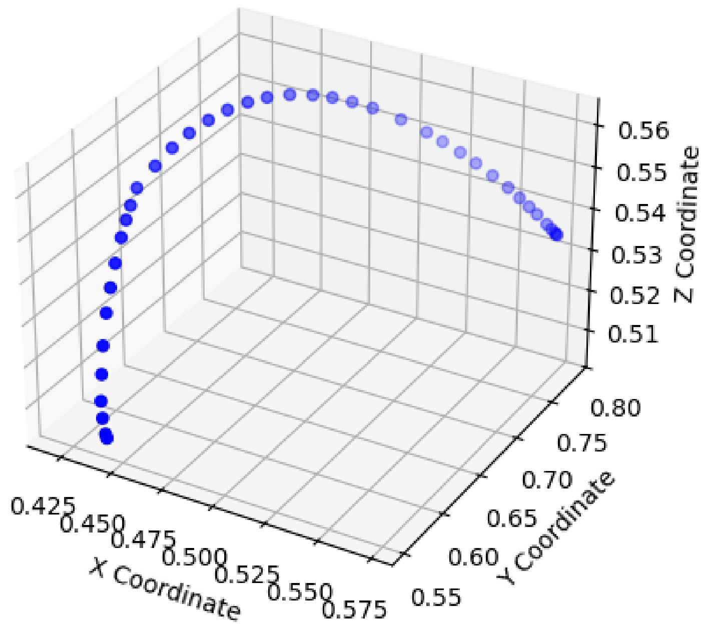

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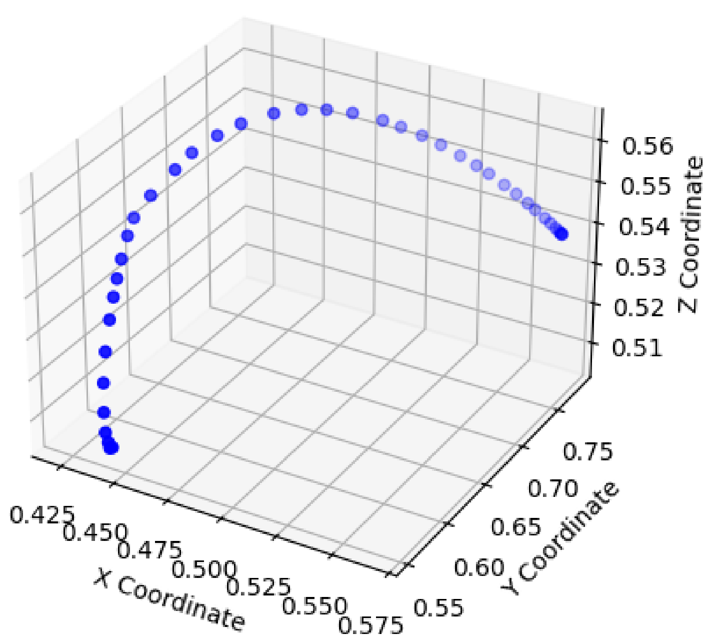

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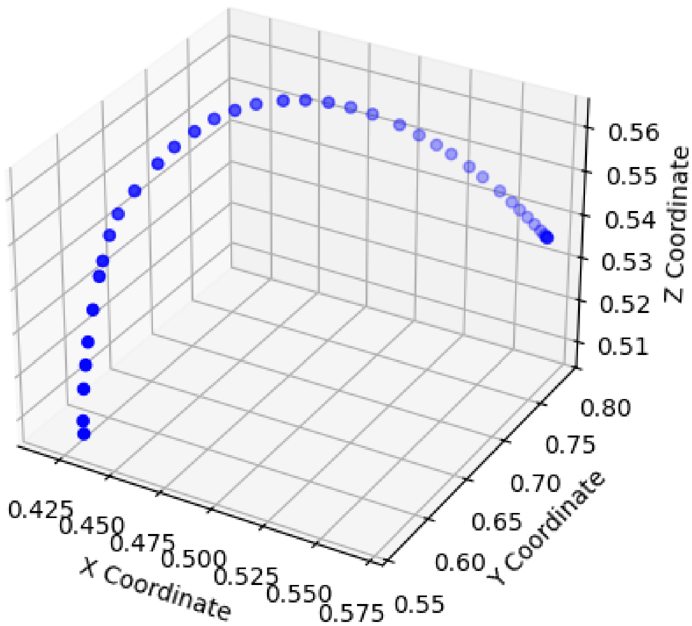
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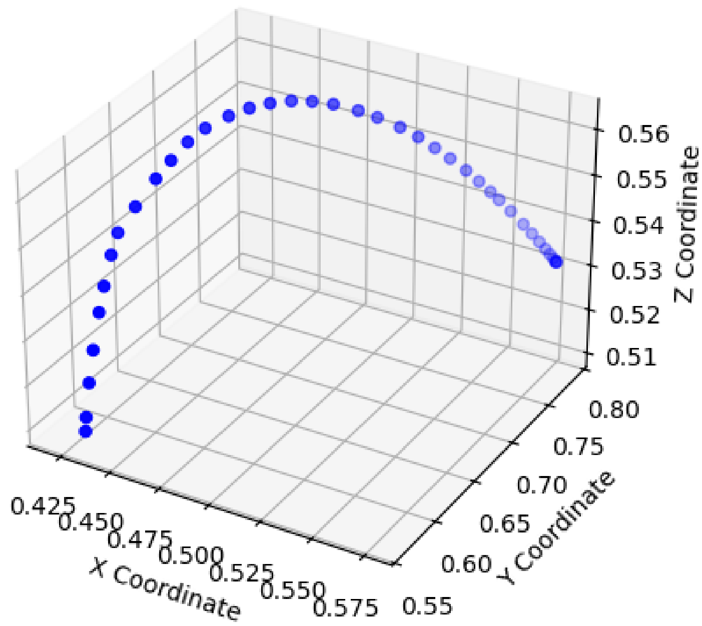

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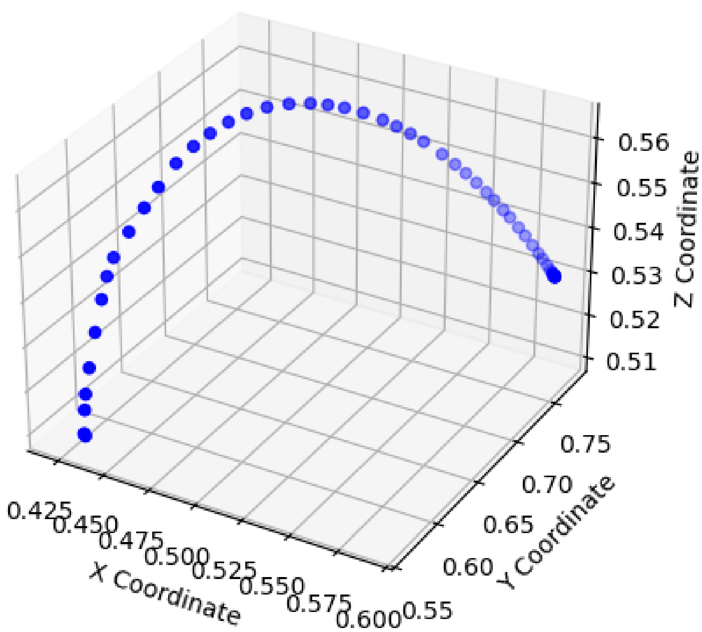
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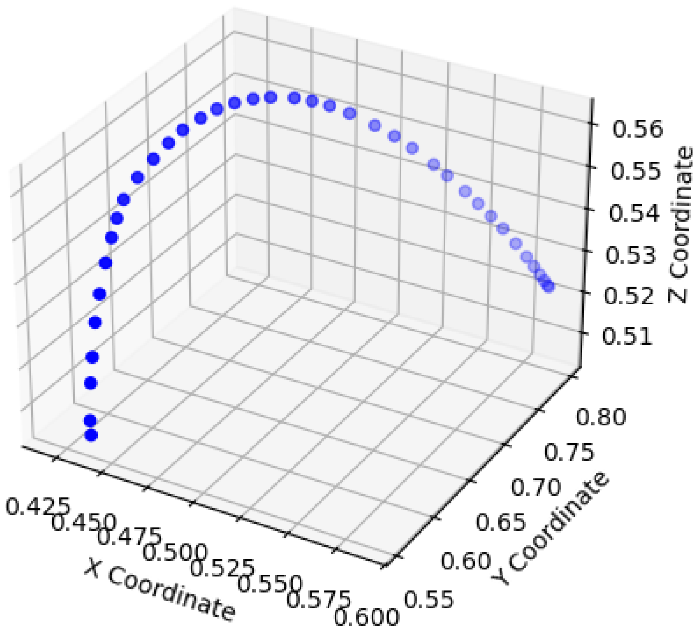
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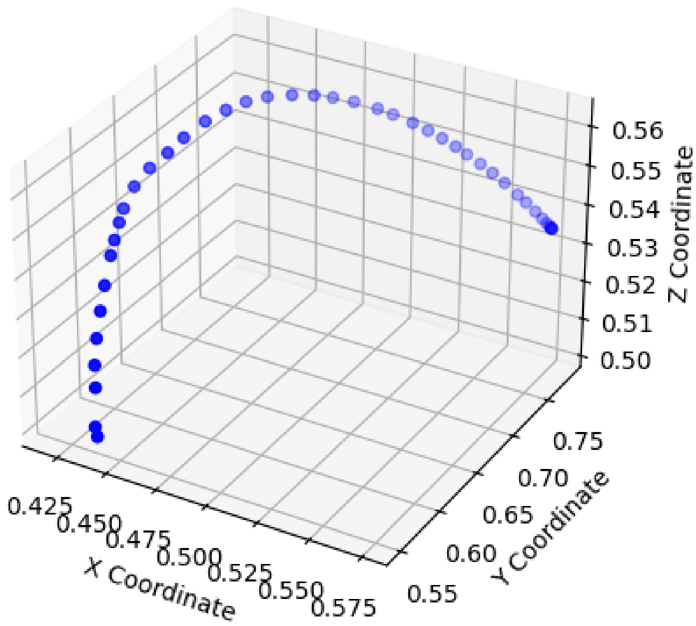
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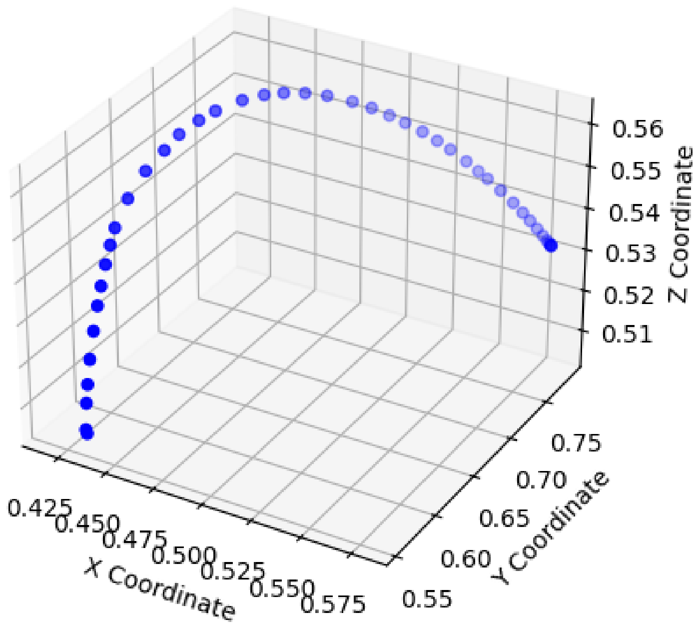

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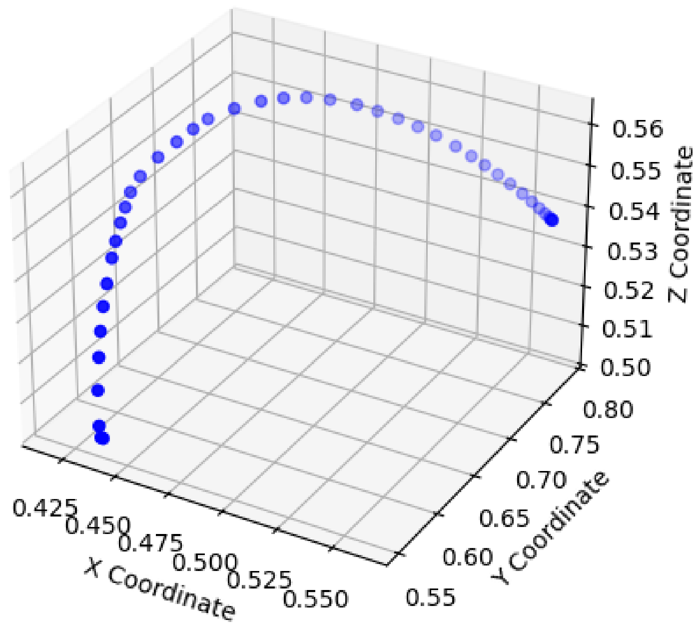
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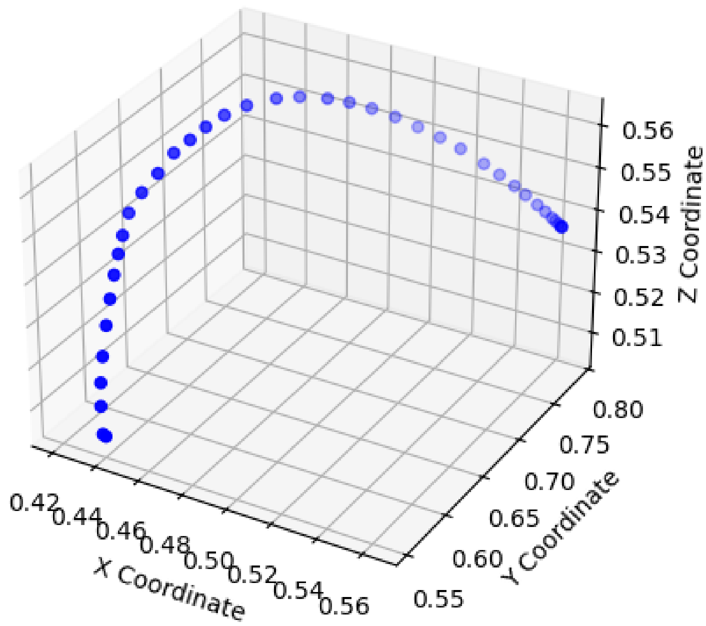
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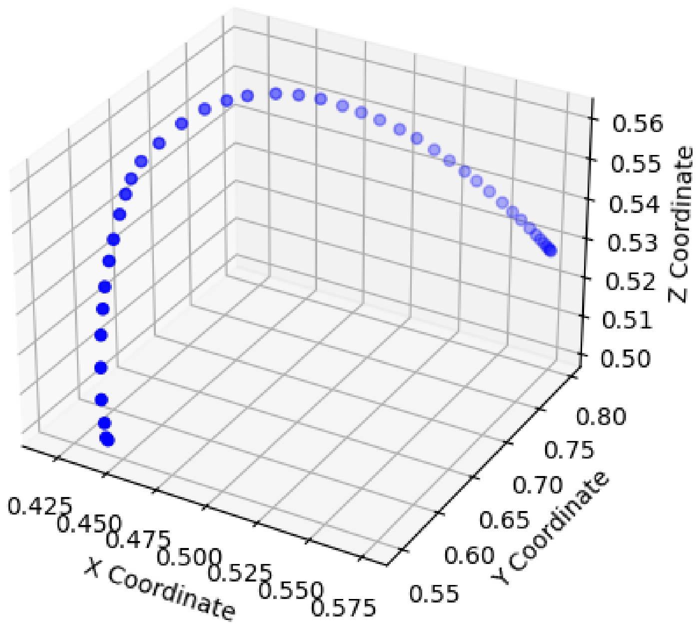

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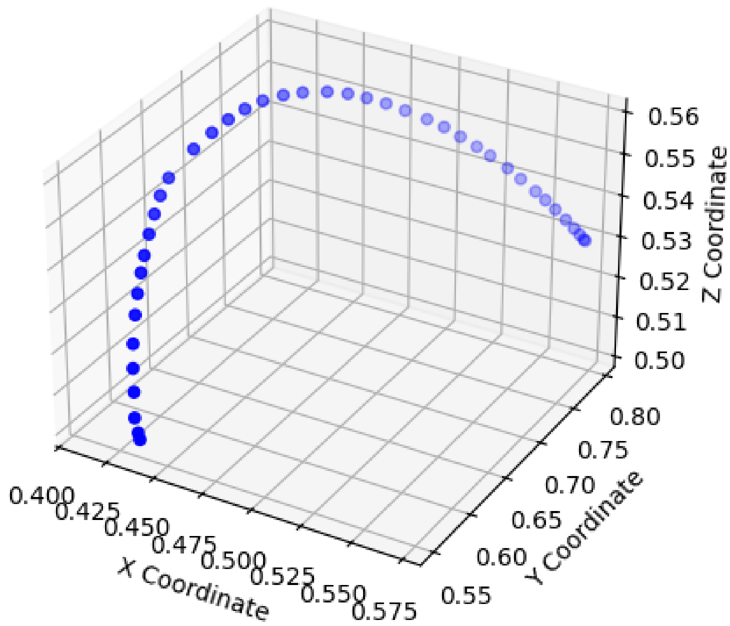

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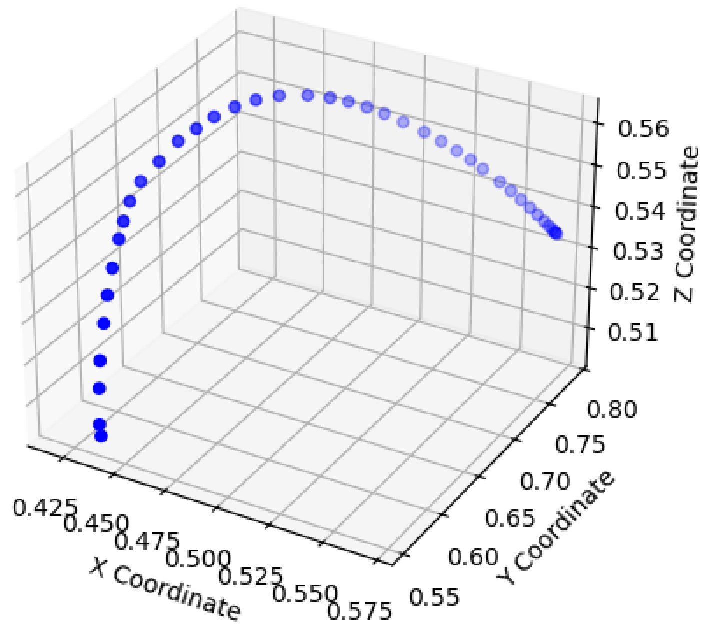
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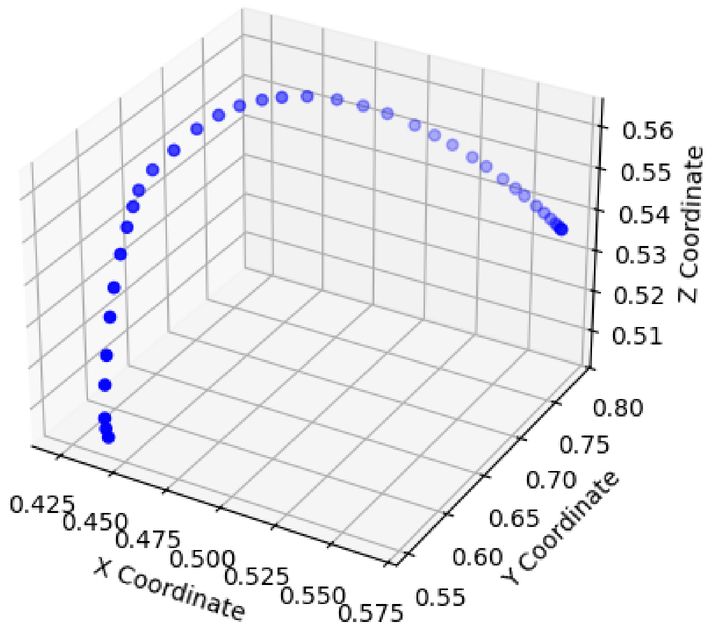
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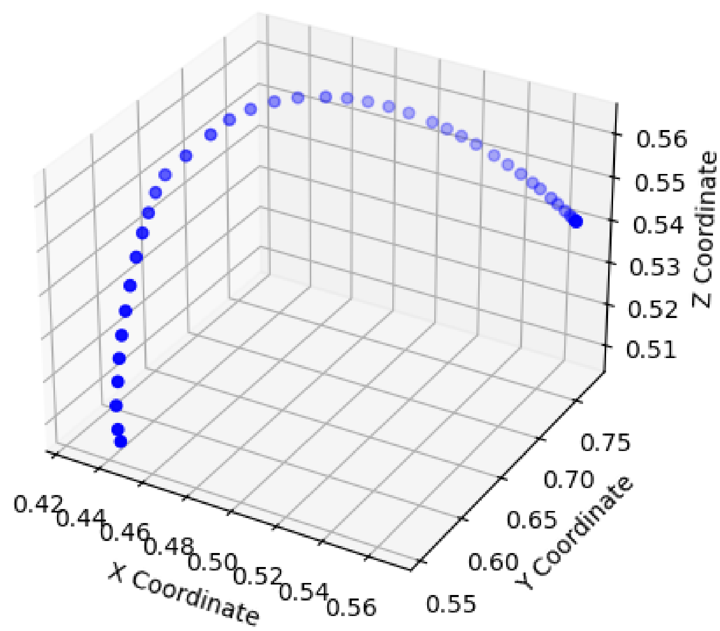
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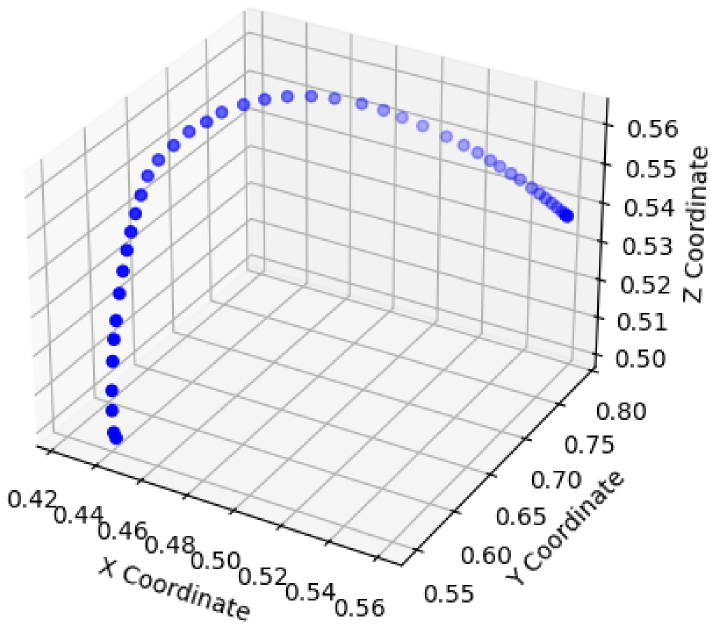

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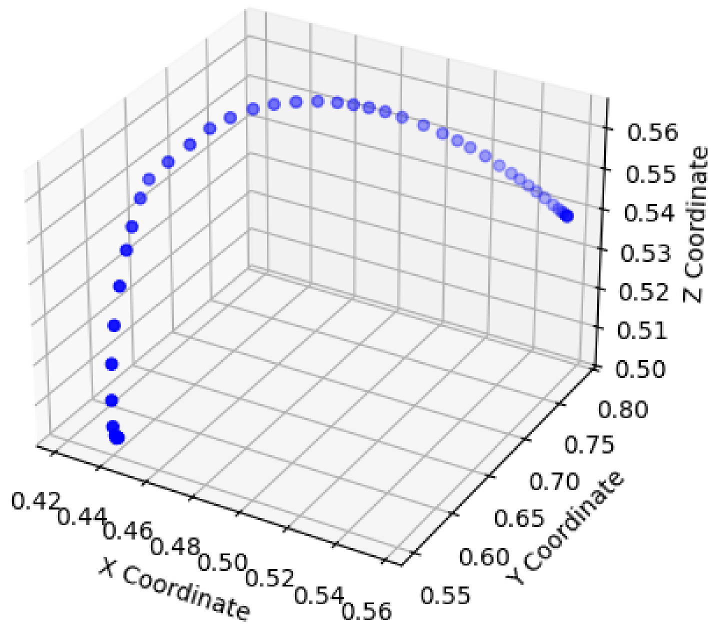
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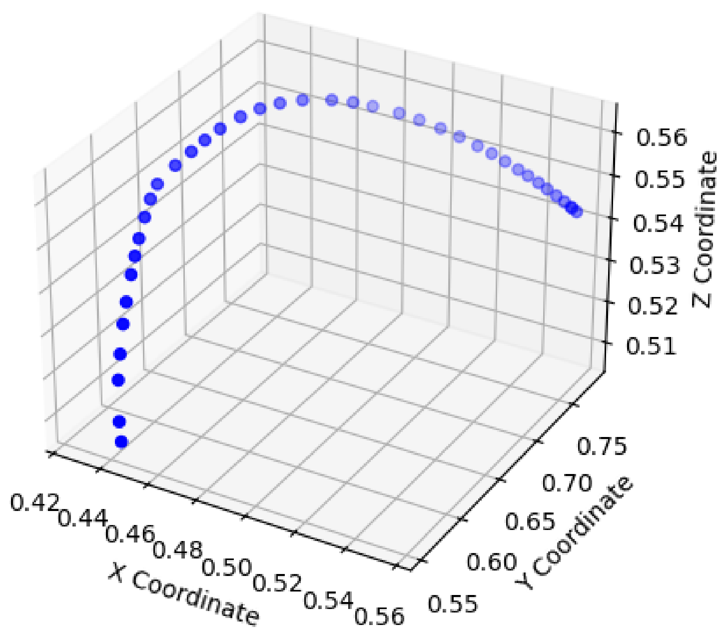

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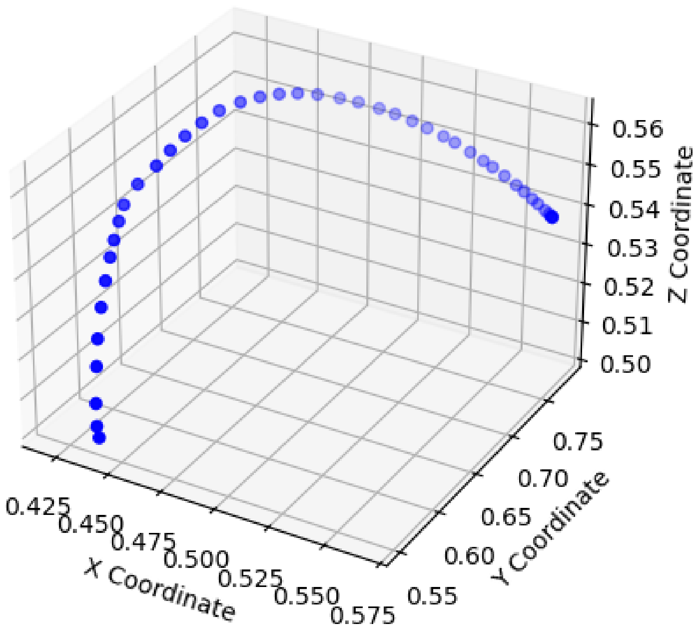

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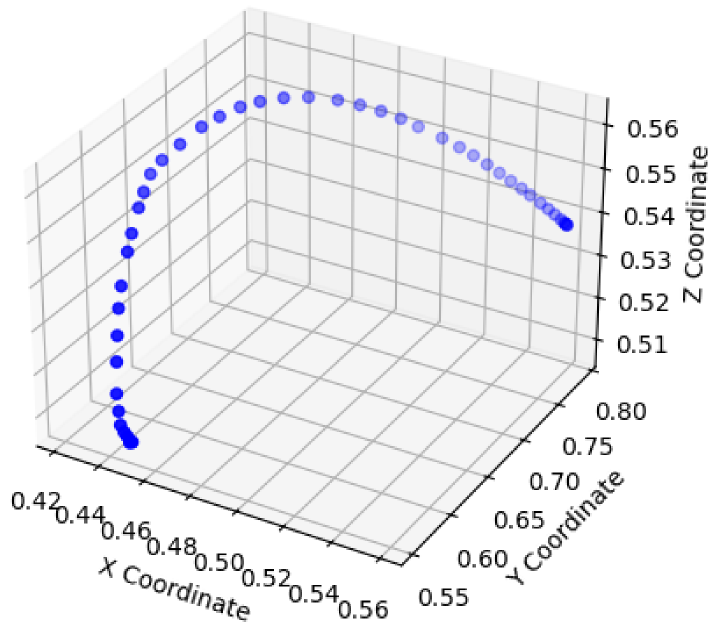
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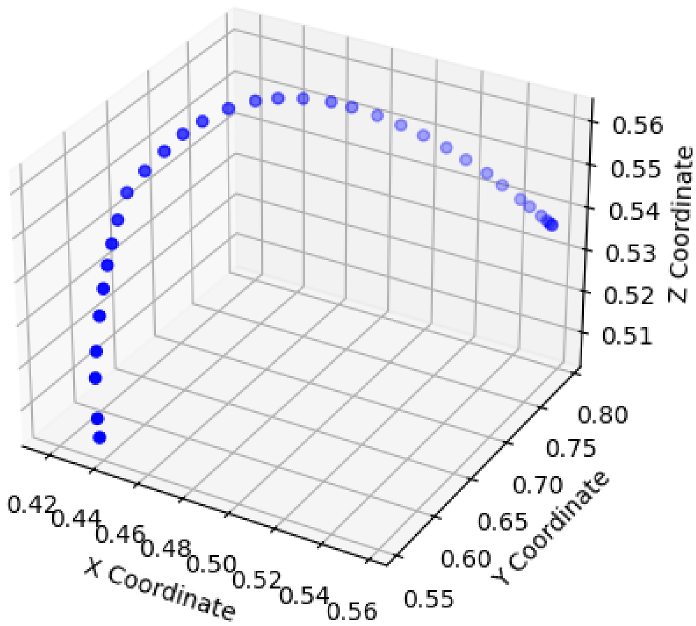
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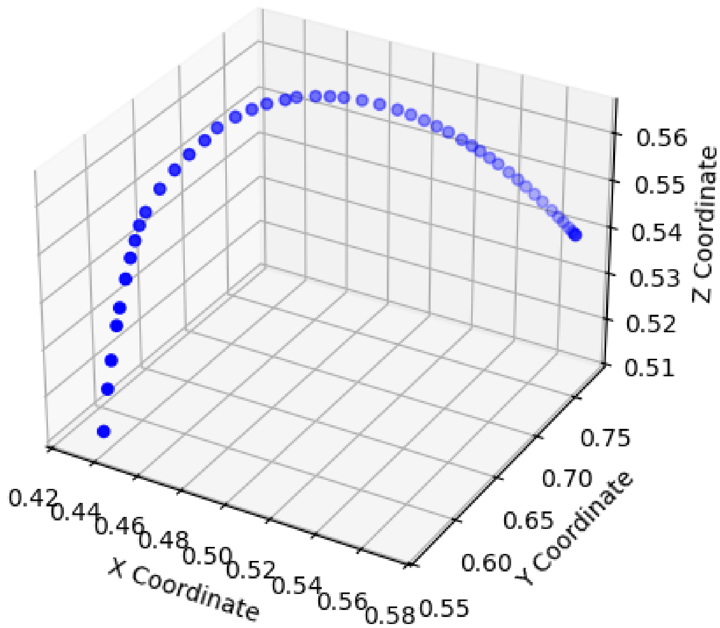
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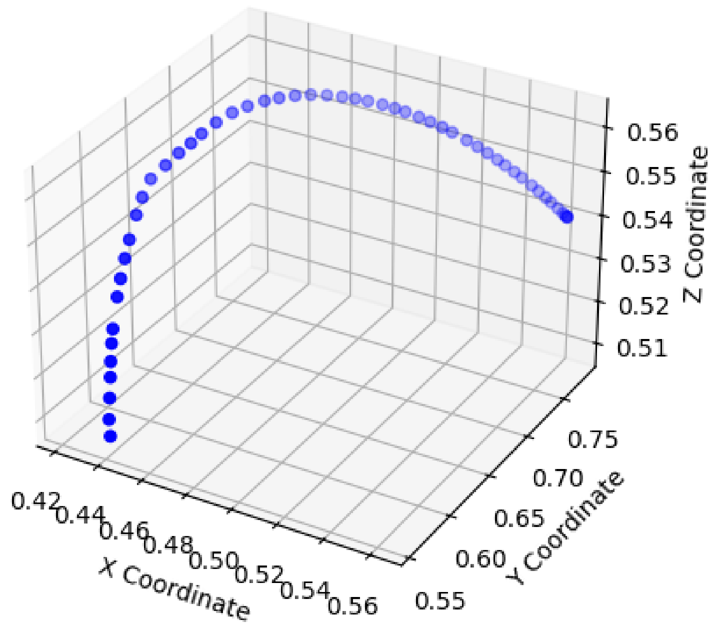
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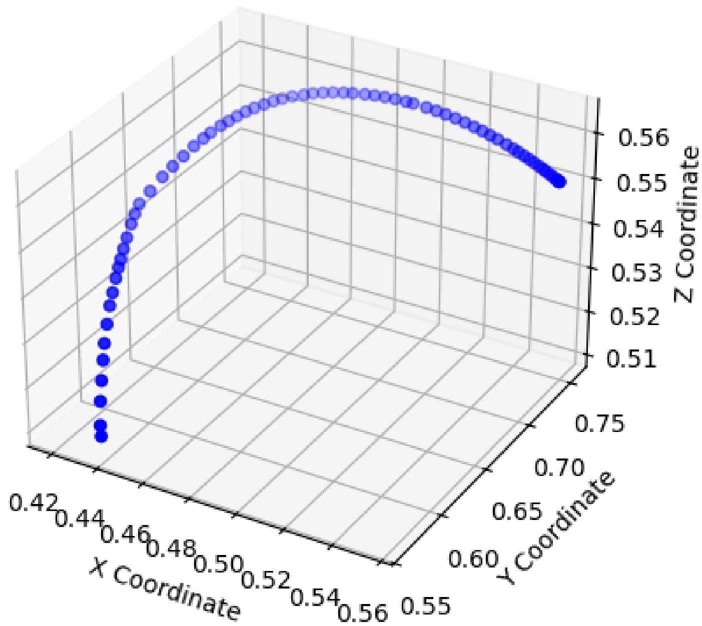

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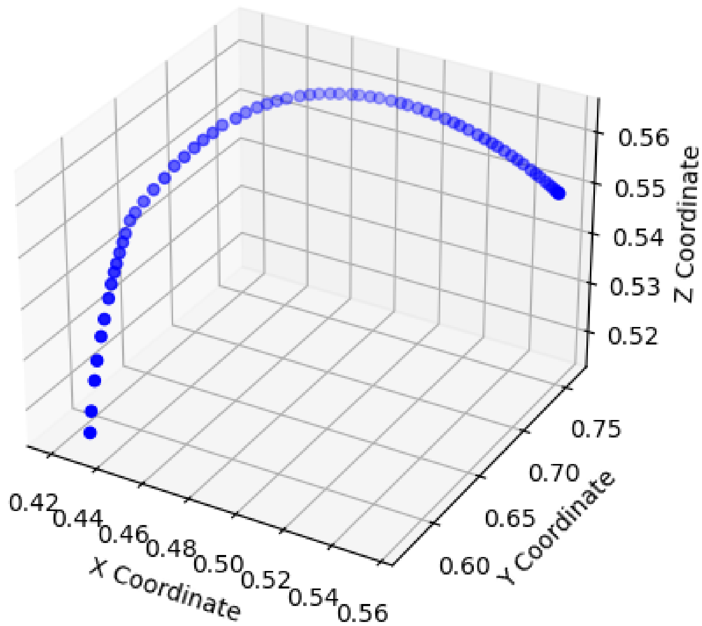
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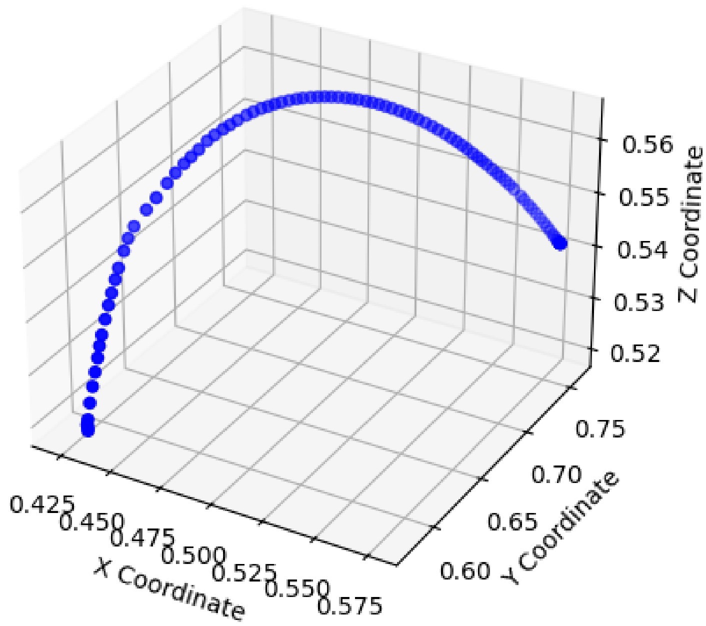
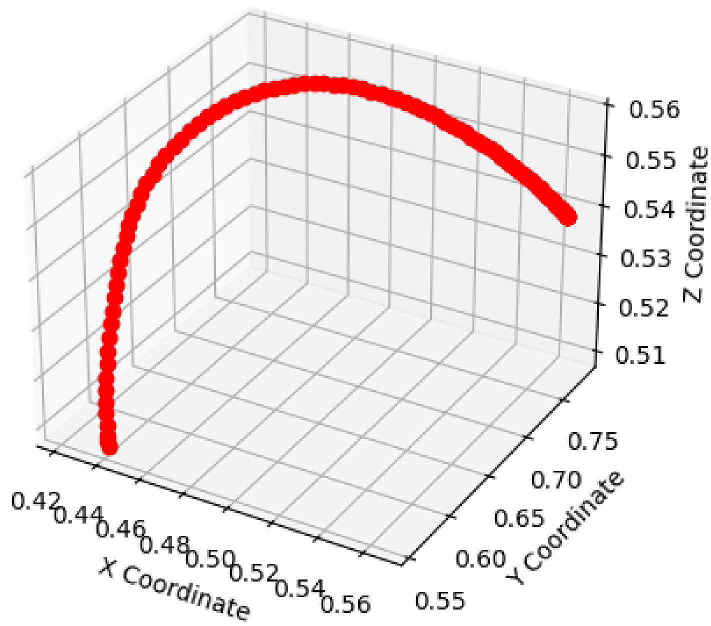


0.0.1

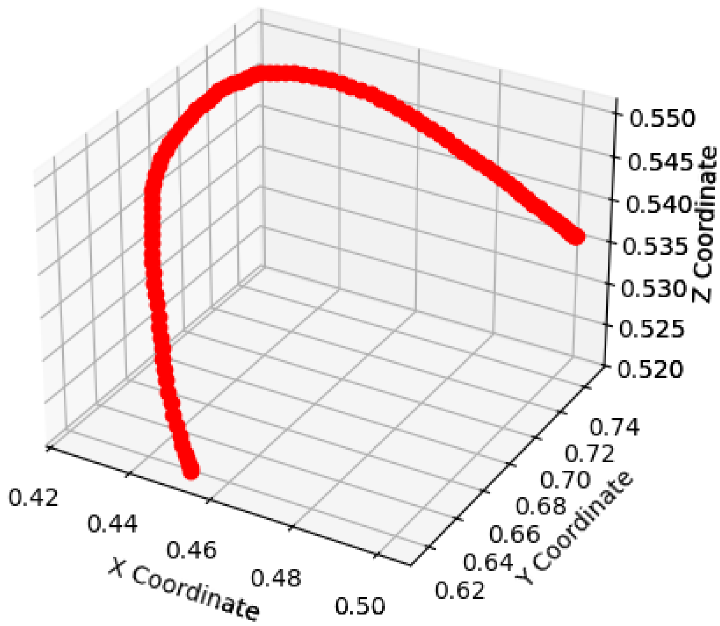
[2]:
```python
%matplotlib widget
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
from scipy.interpolate import interp1d

# Read all sheets from Excel
kole_er_sheets = pd.read_excel("Kole/Kole_ER_BigData.xlsx",
                               engine="calamine",
                               sheet_name=None)

# Decide how many points you want in the "normalized" rep
n_samples = 100

# This list will hold arrays of shape (n_samples, 3) for each rep
all_reps = []
```

```python
for sheet_name, df in kole_er_sheets.items():
    # Ensure 'X', 'Y', and 'Z' columns exist
    if {'X', 'Y', 'Z'}.issubset(df.columns):
        # Number of points in this sheet (rep)
        n_points = len(df)

        # Create a parameter t from 0 to 1 for this rep
        t_original = np.linspace(0, 1, n_points)

        # Create interpolation functions for X, Y, and Z
        fX = interp1d(t_original, df['X'], kind='linear')
        fY = interp1d(t_original, df['Y'], kind='linear')
        fZ = interp1d(t_original, df['Z'], kind='linear')

        # Resample at n_samples points between 0 and 1
        t_resampled = np.linspace(0, 1, n_samples)
        X_resampled = fX(t_resampled)
        Y_resampled = fY(t_resampled)
        Z_resampled = fZ(t_resampled)

        # Stack into shape (n_samples, 3)
        rep_array = np.column_stack((X_resampled, Y_resampled, Z_resampled))
        all_reps.append(rep_array)
    else:
        print(f"Skipping sheet '{sheet_name}' because it doesn't have X, Y, Z␣
↪columns.")

# Convert the list of reps into a 3D NumPy array of shape (num_reps, n_samples,␣
↪3)
all_reps = np.array(all_reps)

# Compute the average across all reps (mean along axis=0),
# resulting in shape (n_samples, 3)
avg_rep = np.mean(all_reps, axis=0)

# Plot the average rep
fig = plt.figure("Average Kole ER Rep")
ax = fig.add_subplot(111, projection='3d')

# You can use plot(...) for a line or scatter(...) for points
ax.plot(avg_rep[:, 0], avg_rep[:, 1], avg_rep[:, 2], c='red', marker='o')

ax.set_xlabel('X Coordinate')
ax.set_ylabel('Y Coordinate')
ax.set_zlabel('Z Coordinate')

plt.show()
```



[4]:
```
%matplotlib widget
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
from scipy.interpolate import interp1d

# Read all sheets from Excel
kole_er_sheets = pd.read_excel("Kam/Kam_ER_BigData.xlsx",
                               engine="calamine",
                               sheet_name=None)

# Decide how many points you want in the "normalized" rep
n_samples = 100

# This list will hold arrays of shape (n_samples, 3) for each rep
all_reps = []

for sheet_name, df in kole_er_sheets.items():
    # Ensure 'X', 'Y', and 'Z' columns exist
    if {'X', 'Y', 'Z'}.issubset(df.columns):
```

```
        # Number of points in this sheet (rep)
        n_points = len(df)

        # Create a parameter t from 0 to 1 for this rep
        t_original = np.linspace(0, 1, n_points)

        # Create interpolation functions for X, Y, and Z
        fX = interp1d(t_original, df['X'], kind='linear')
        fY = interp1d(t_original, df['Y'], kind='linear')
        fZ = interp1d(t_original, df['Z'], kind='linear')

        # Resample at n_samples points between 0 and 1
        t_resampled = np.linspace(0, 1, n_samples)
        X_resampled = fX(t_resampled)
        Y_resampled = fY(t_resampled)
        Z_resampled = fZ(t_resampled)

        # Stack into shape (n_samples, 3)
        rep_array = np.column_stack((X_resampled, Y_resampled, Z_resampled))
        all_reps.append(rep_array)
    else:
        print(f"Skipping sheet '{sheet_name}' because it doesn't have X, Y, Z␣
↪columns.")

# Convert the list of reps into a 3D NumPy array of shape (num_reps, n_samples,␣
↪3)
all_reps = np.array(all_reps)

# Compute the average across all reps (mean along axis=0),
# resulting in shape (n_samples, 3)
avg_rep = np.mean(all_reps, axis=0)

# Plot the average rep
fig = plt.figure("Average Kam ER Rep")
ax = fig.add_subplot(111, projection='3d')

# You can use plot(...) for a line or scatter(...) for points
ax.plot(avg_rep[:, 0], avg_rep[:, 1], avg_rep[:, 2], c='red', marker='o')

ax.set_xlabel('X Coordinate')
ax.set_ylabel('Y Coordinate')
ax.set_zlabel('Z Coordinate')

plt.show()
```

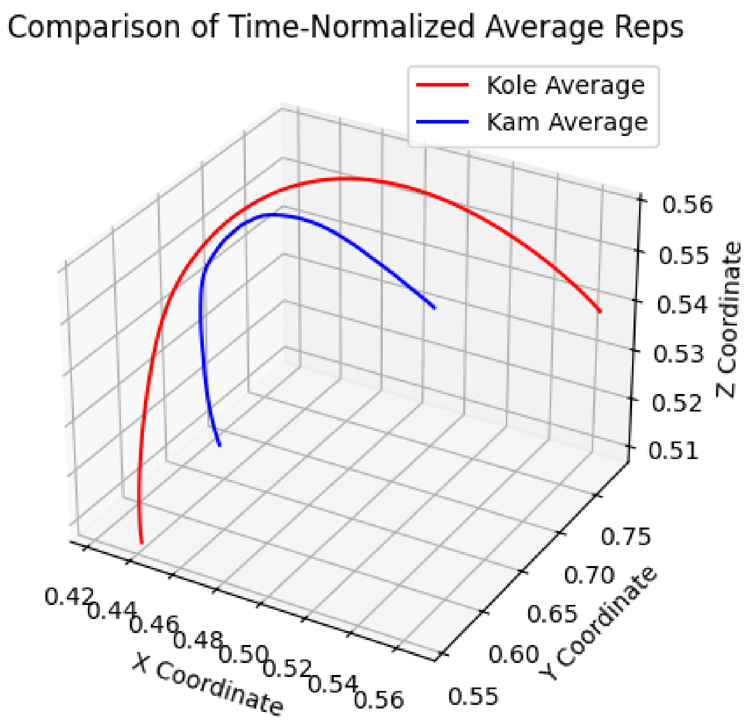


[5]:

```
%matplotlib widget
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
from scipy.interpolate import interp1d

def compute_average_rep(file_path, n_samples=100):
    """
    Reads all sheets in an Excel file, time-normalizes each rep to n_samples,
    and returns the averaged (X, Y, Z) trajectory as a NumPy array of shape␣
↪(n_samples, 3).
    """
    # Read all sheets from the given file
    sheets = pd.read_excel(file_path, engine="calamine", sheet_name=None)

    all_reps = []  # will store arrays of shape (n_samples, 3) for each rep

    for sheet_name, df in sheets.items():
        # Check that the DataFrame has the necessary columns
        if {'X', 'Y', 'Z'}.issubset(df.columns):
```

```
            n_points = len(df)
            # Parametrize from 0 to 1
            t_original = np.linspace(0, 1, n_points)

            # Create interpolation functions for X, Y, Z
            fX = interp1d(t_original, df['X'], kind='linear')
            fY = interp1d(t_original, df['Y'], kind='linear')
            fZ = interp1d(t_original, df['Z'], kind='linear')

            # Resample at n_samples points
            t_resampled = np.linspace(0, 1, n_samples)
            X_resampled = fX(t_resampled)
            Y_resampled = fY(t_resampled)
            Z_resampled = fZ(t_resampled)

            rep_array = np.column_stack((X_resampled, Y_resampled, Z_resampled))
            all_reps.append(rep_array)
        else:
            print(f"Skipping sheet '{sheet_name}' because it doesn't have X, Y,␣
 ↪Z columns.")

    # Convert to a NumPy array of shape (num_reps, n_samples, 3)
    all_reps = np.array(all_reps)

    # Average across all reps, resulting in shape (n_samples, 3)
    avg_rep = np.mean(all_reps, axis=0)

    return avg_rep

# Compute average reps from the two files
kole_avg = compute_average_rep("Kole/Kole_ER_BigData.xlsx", n_samples=100)
kam_avg = compute_average_rep("Kam/Kam_ER_BigData.xlsx", n_samples=100)

# Plot the two average reps in the same 3D figure
fig = plt.figure("Comparison of Average Reps")
ax = fig.add_subplot(111, projection='3d')

# Plot Kole's average rep (red line)
ax.plot(kole_avg[:, 0], kole_avg[:, 1], kole_avg[:, 2], color='red',␣
 ↪label='Kole Average')

# Plot Kam's average rep (blue line)
ax.plot(kam_avg[:, 0], kam_avg[:, 1], kam_avg[:, 2], color='blue', label='Kam␣
 ↪Average')

# Label the axes
ax.set_xlabel('X Coordinate')
```

```
ax.set_ylabel('Y Coordinate')
ax.set_zlabel('Z Coordinate')

ax.set_title('Comparison of Time-Normalized Average Reps')
ax.legend()

plt.show()
```



[6]:
```
import numpy as np

def compute_jerk_measure(trajectory):
    """
    trajectory: (N, 3) array of (X, Y, Z) positions
                time-normalized from t=0 to t=1.
    Returns a scalar representing the integrated jerk magnitude.
    """
    N = trajectory.shape[0]

    # Assume uniform time spacing from 0..1
    # dt = total_time / (N-1). If total_time=1, then dt=1/(N-1).
```

```python
    dt = 1.0 / (N - 1)

    # 1) velocity
    vel = np.gradient(trajectory, dt, axis=0)  # shape (N, 3)
    # 2) acceleration
    acc = np.gradient(vel, dt, axis=0)        # shape (N, 3)
    # 3) jerk
    jerk = np.gradient(acc, dt, axis=0)       # shape (N, 3)

    # Magnitude of jerk at each sample
    jerk_mag = np.linalg.norm(jerk, axis=1)   # shape (N, )

    # Integrate jerk magnitude over the duration 0..1
    # You can also use sum(jerk_mag)*dt as a simpler approximation
    jerk_measure = np.trapz(jerk_mag, dx=dt)
    return jerk_measure

# Suppose you have average reps for Kole and Kam as Nx3 arrays
jerk_kole = compute_jerk_measure(kole_avg)
jerk_kam  = compute_jerk_measure(kam_avg)

print(f"Kole's integrated jerk measure: {jerk_kole:.4f}")
print(f"Kam's integrated jerk measure:  {jerk_kam:.4f}")
```

```
Kole's integrated jerk measure: 35.9972
Kam's integrated jerk measure:  34.6264
```

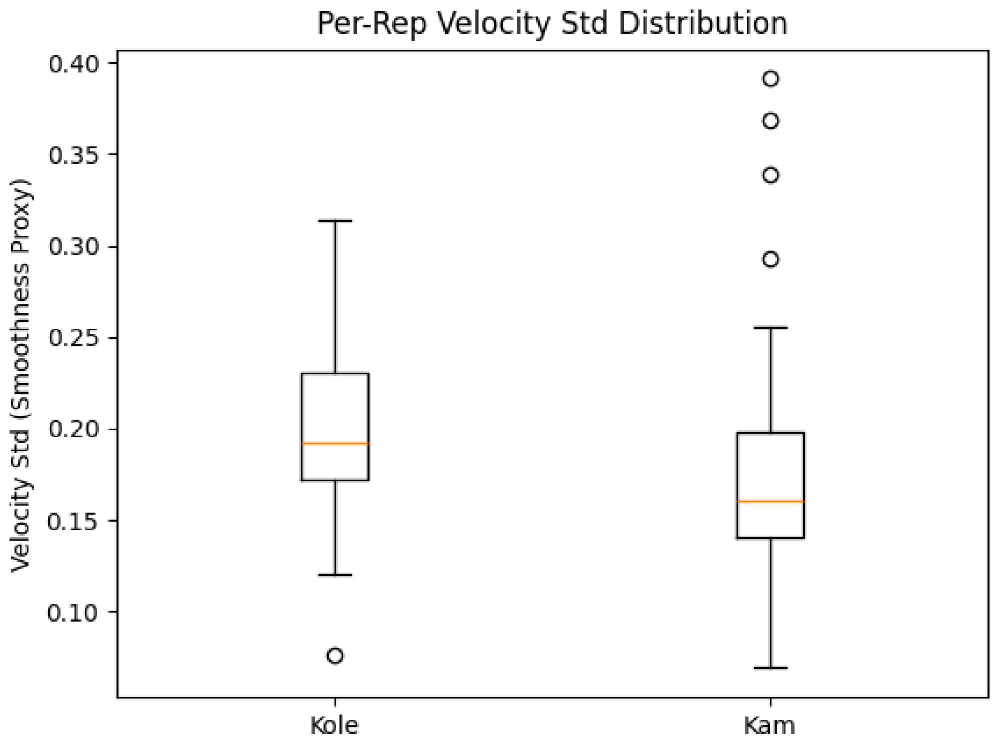
```
/tmp/ipykernel_210142/1341065964.py:27: DeprecationWarning: `trapz` is
deprecated. Use `trapezoid` instead, or one of the numerical integration
functions in `scipy.integrate`.
  jerk_measure = np.trapz(jerk_mag, dx=dt)
```

[7]:
```python
%matplotlib widget
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
from scipy.interpolate import interp1d

def time_normalize_rep(df, n_samples=100):
    """
    Given a DataFrame `df` containing columns 'X', 'Y', 'Z' for a single rep,
    returns a time-normalized NumPy array of shape (n_samples, 3).
    """
    # Number of points in the original rep
    n_points = len(df)

    # Create a parameter from 0 to 1
```

```
    t_original = np.linspace(0, 1, n_points)

    # Create interpolation functions for each coordinate
    fX = interp1d(t_original, df['X'], kind='linear')
    fY = interp1d(t_original, df['Y'], kind='linear')
    fZ = interp1d(t_original, df['Z'], kind='linear')

    # Resample at n_samples points
    t_resampled = np.linspace(0, 1, n_samples)
    X_resampled = fX(t_resampled)
    Y_resampled = fY(t_resampled)
    Z_resampled = fZ(t_resampled)

    # Return (n_samples, 3)
    return np.column_stack((X_resampled, Y_resampled, Z_resampled))

def compute_velocity_std(trajectory):
    """
    Given a time-normalized trajectory of shape (N, 3),
    computes the standard deviation of the velocity magnitude.
    """
    N = trajectory.shape[0]
    if N < 2:
        return np.nan  # Not enough points to compute velocity

    # Assume uniform time spacing from 0..1
    dt = 1.0 / (N - 1)

    # Approximate velocity using finite differences
    velocity = np.gradient(trajectory, dt, axis=0)  # shape: (N, 3)

    # Magnitude of velocity at each sample
    vel_mag = np.linalg.norm(velocity, axis=1)      # shape: (N,)

    # Standard deviation of velocity magnitude
    return np.std(vel_mag)

def process_file(file_path, n_samples=100):
    """
    Reads all sheets from `file_path`, time-normalizes each rep (sheet),
    computes velocity std for each, and returns a list of those values.
    """
    sheets = pd.read_excel(file_path, engine="calamine", sheet_name=None)

    vel_stds = []

    for sheet_name, df in sheets.items():
```

```python
        # Check for required columns
        if {'X', 'Y', 'Z'}.issubset(df.columns):
            # Time-normalize this rep
            rep_array = time_normalize_rep(df, n_samples=n_samples)
            # Compute velocity std
            v_std = compute_velocity_std(rep_array)
            vel_stds.append(v_std)
        else:
            print(f"Skipping sheet '{sheet_name}' (missing X, Y, or Z).")

    return vel_stds

# --- Usage Example ---

# 1) Compute velocity std for each rep in Kole's file
kole_vel_stds = process_file("Kole/Kole_ER_BigData.xlsx", n_samples=100)

# 2) Compute velocity std for each rep in Kam's file
kam_vel_stds = process_file("Kam/Kam_ER_BigData.xlsx", n_samples=100)

# 3) Compute summary statistics
kole_mean = np.mean(kole_vel_stds)
kole_std  = np.std(kole_vel_stds)

kam_mean = np.mean(kam_vel_stds)
kam_std  = np.std(kam_vel_stds)

# Optional: visualize the distribution (e.g. boxplot)
fig, ax = plt.subplots()
ax.boxplot([kole_vel_stds, kam_vel_stds], labels=['Kole', 'Kam'])
ax.set_ylabel('Velocity Std (Smoothness Proxy)')
ax.set_title('Per-Rep Velocity Std Distribution')
plt.show()
```

```
/tmp/ipykernel_210142/1074405839.py:93: MatplotlibDeprecationWarning: The
'labels' parameter of boxplot() has been renamed 'tick_labels' since Matplotlib
3.9; support for the old name will be dropped in 3.11.
  ax.boxplot([kole_vel_stds, kam_vel_stds], labels=['Kole', 'Kam'])
```

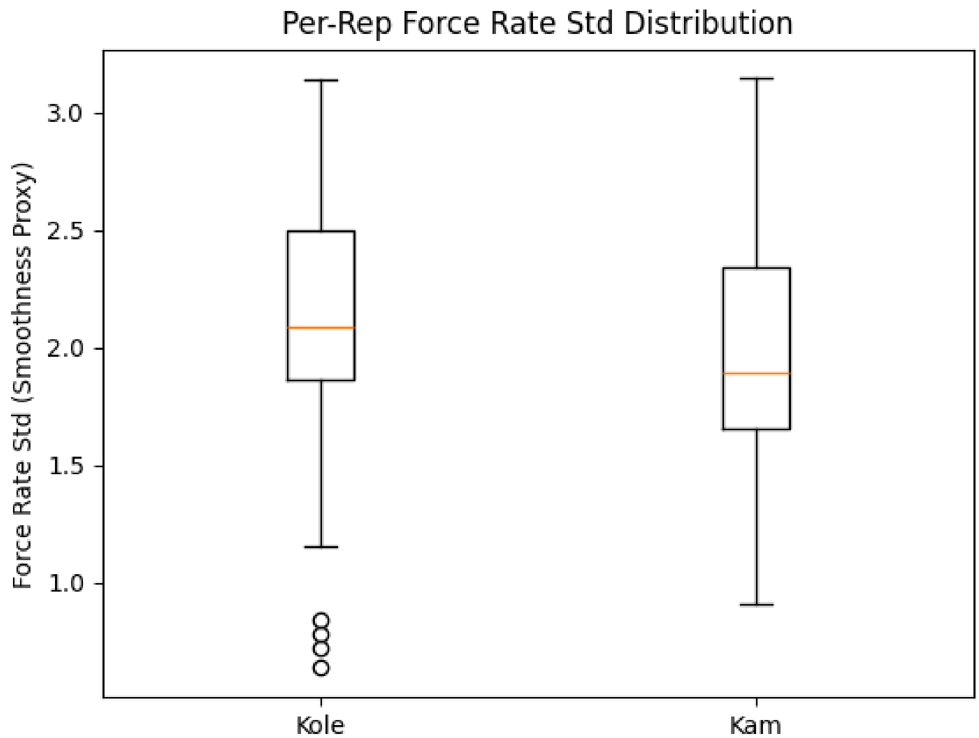


[8]:
```python
from scipy.interpolate import interp1d
import numpy as np

def time_normalize_force(df, n_samples=100):
    """
    Given a DataFrame `df` with a 'Force' column, returns a time-normalized
    1D NumPy array of shape (n_samples,).
    """
    n_points = len(df)
    if n_points < 2:
        return None  # Not enough points to interpolate

    # Parametrize from 0..1
    t_original = np.linspace(0, 1, n_points)

    # Interpolate the 'Force' column
    fF = interp1d(t_original, df['Force'], kind='linear')

    # Resample
    t_resampled = np.linspace(0, 1, n_samples)
    force_resampled = fF(t_resampled)  # shape (n_samples,)
```

```python
    return force_resampled

def compute_force_rate_std(force_array):
    """
    Given a time-normalized 1D array of Force values (length N),
    computes the standard deviation of the derivative of Force (dF/dt).
    """
    N = len(force_array)
    if N < 2:
        return np.nan

    # Time step assuming t in [0,1]
    dt = 1.0 / (N - 1)

    # Approximate derivative (Force rate)
    force_rate = np.gradient(force_array, dt)  # shape (N,)

    # Standard deviation of the Force rate
    return np.std(force_rate)

import pandas as pd

def process_force_file(file_path, n_samples=100):
    """
    Reads all sheets from `file_path`, time-normalizes the 'Force' column,
    and computes a smoothness measure (Force rate std) for each rep.
    Returns a list of those per-rep values.
    """
    sheets = pd.read_excel(file_path, engine="calamine", sheet_name=None)
    force_rate_stds = []

    for sheet_name, df in sheets.items():
        # Check if 'Force' column exists
        if 'Force' in df.columns:
            force_array = time_normalize_force(df, n_samples=n_samples)
            if force_array is not None:
                #fr_std = compute_force_rate_std(force_array)
                fr_std = np.std(force_array)
                force_rate_stds.append(fr_std)
            else:
                print(f"Sheet '{sheet_name}' has too few points to interpolate.
↪")
        else:
            print(f"Sheet '{sheet_name}' missing 'Force' column. Skipping.")

    return force_rate_stds
```

```python
import numpy as np
import matplotlib.pyplot as plt

# 1) Process each file
kole_force_rate_stds = process_force_file("Kole/Kole_ER_BigData.xlsx",␣
↪n_samples=100)
kam_force_rate_stds  = process_force_file("Kam/Kam_ER_BigData.xlsx",␣
↪n_samples=100)

# 2) Summary statistics
kole_mean = np.mean(kole_force_rate_stds)
kole_std  = np.std(kole_force_rate_stds)

kam_mean = np.mean(kam_force_rate_stds)
kam_std  = np.std(kam_force_rate_stds)

print(f"Kole - Mean: {kole_mean:.4f}, SD across reps: {kole_std:.4f}\n")

print(f"Kam - Mean: {kam_mean:.4f}, SD across reps: {kam_std:.4f}")

# 3) Boxplot comparison
fig, ax = plt.subplots()
ax.boxplot([kole_force_rate_stds, kam_force_rate_stds], labels=['Kole', 'Kam'])
ax.set_ylabel('Force Rate Std (Smoothness Proxy)')
ax.set_title('Per-Rep Force Rate Std Distribution')
plt.show()
```

```
Kole - Mean: 2.1177, SD across reps: 0.5477

Kam - Mean: 1.9500, SD across reps: 0.5482

/tmp/ipykernel_210142/1840085238.py:89: MatplotlibDeprecationWarning: The
'labels' parameter of boxplot() has been renamed 'tick_labels' since Matplotlib
3.9; support for the old name will be dropped in 3.11.
  ax.boxplot([kole_force_rate_stds, kam_force_rate_stds], labels=['Kole',
'Kam'])
```



[9]:
```python
import numpy as np
import pandas as pd
from scipy.interpolate import interp1d

def time_normalize_force(df, n_samples=100):
    n_points = len(df)
    if n_points < 2:
        return None

    t_original = np.linspace(0, 1, n_points)
    fF = interp1d(t_original, df['Force'], kind='linear')

    t_resampled = np.linspace(0, 1, n_samples)
    force_resampled = fF(t_resampled)
    return force_resampled

def extract_force_features(force_array):
    """
    force_array: 1D array of time-normalized Force data
    returns (peak_force, time_to_peak)
    """
```

```
    peak_idx = np.argmax(force_array)
    peak_force = force_array[peak_idx]
    # Convert index to a fraction of total time [0..1]
    time_to_peak = peak_idx / (len(force_array) - 1)
    return peak_force, time_to_peak

def process_file_for_features(file_path, n_samples=100):
    sheets = pd.read_excel(file_path, engine="calamine", sheet_name=None)
    peaks = []
    times = []

    for sheet_name, df in sheets.items():
        if 'Force' in df.columns:
            f_arr = time_normalize_force(df, n_samples=n_samples)
            if f_arr is not None:
                pf, ttp = extract_force_features(f_arr)
                peaks.append(pf)
                times.append(ttp)
        else:
            print(f"Skipping {sheet_name} (no Force column).")

    return np.array(peaks), np.array(times)

# Example usage for Kole and Kam:
kole_peaks, kole_times = process_file_for_features("Kole/Kole_ER_BigData.xlsx")
kam_peaks, kam_times   = process_file_for_features("Kam/Kam_ER_BigData.xlsx")

# Now compare distributions of peak force and time to peak:
print("Kole Peak Force stats:", np.mean(kole_peaks), np.std(kole_peaks))
print("Kam Peak Force stats:", np.mean(kam_peaks),  np.std(kam_peaks))

print("Kole Time to Peak stats:", np.mean(kole_times), np.std(kole_times))
print("Kam Time to Peak stats:", np.mean(kam_times),  np.std(kam_times))
```

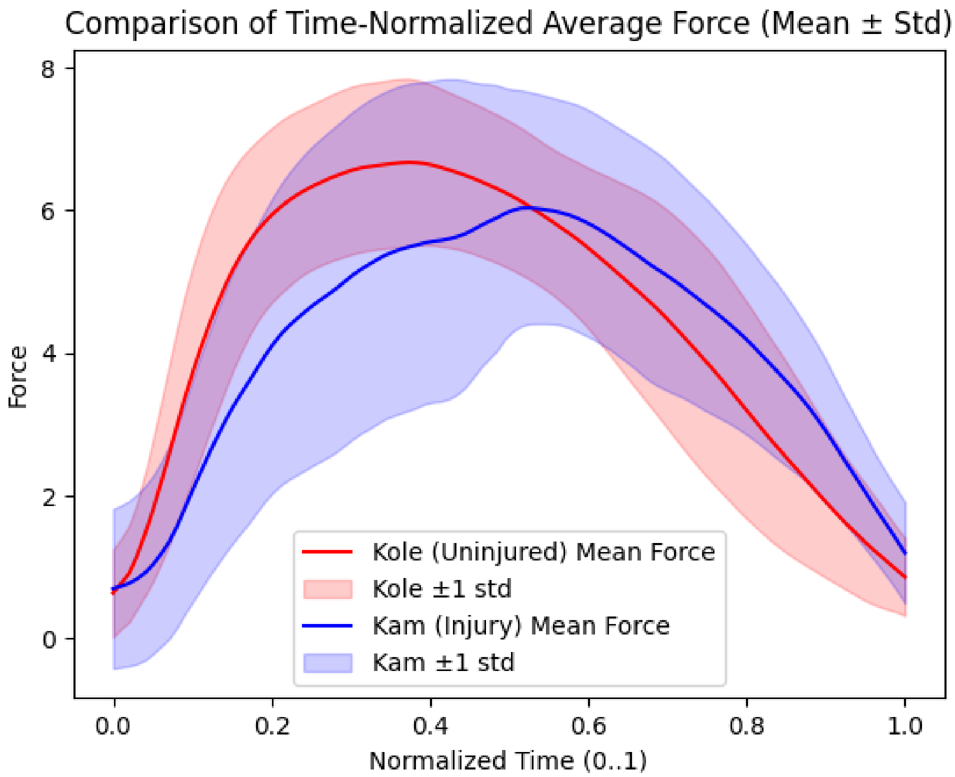
```
Kole Peak Force stats: 7.060513285155572 1.0689060780114197
Kam Peak Force stats: 6.5918227552256985 1.3896352649081045
Kole Time to Peak stats: 0.374534821903243 0.09976321261447416
Kam Time to Peak stats: 0.44484848484848494 0.14282071044175865
```

[18]:

```
%matplotlib widget
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.interpolate import interp1d

def time_normalize_force(df, n_samples=100):
    """
```

```
    Given a DataFrame `df` with a 'Force' column, returns a 1D array of length␣
↪n_samples
    representing the time-normalized Force data from t=0..1.
    """
    if 'Force' not in df.columns:
        return None

    n_points = len(df)
    if n_points < 2:
        return None  # Not enough data to interpolate

    # Original time parameter from 0..1
    t_original = np.linspace(0, 1, n_points)

    # Interpolation function for Force
    f_force = interp1d(t_original, df['Force'], kind='linear')

    # Resample to n_samples points in [0, 1]
    t_resampled = np.linspace(0, 1, n_samples)
    force_resampled = f_force(t_resampled)  # shape: (n_samples,)

    return force_resampled

def read_time_normalized_forces(file_path, n_samples=100):
    """
    Reads all sheets from the given Excel file, time-normalizes the 'Force'␣
↪column
    in each sheet to n_samples points, and returns a 2D array of shape␣
↪(num_reps, n_samples).
    """
    # Read all sheets as a dict of {sheet_name: DataFrame}
    sheets = pd.read_excel(file_path, engine="calamine", sheet_name=None)

    all_forces = []
    for sheet_name, df in sheets.items():
        # Time-normalize the Force data in this sheet
        force_array = time_normalize_force(df, n_samples=n_samples)
        if force_array is not None:
            all_forces.append(force_array)
        else:
            print(f"Skipping sheet '{sheet_name}' (no Force column or␣
↪insufficient data).")

    if len(all_forces) == 0:
        print(f"No valid Force data found in {file_path}.")
        return None
```

```python
    # Convert list of 1D arrays into a 2D array: (num_reps, n_samples)
    return np.array(all_forces)

# -------------------------------
# Main: Compute and Plot Mean ± Std
# -------------------------------

# 1. Read time-normalized forces for each file
n_samples = 100
kole_forces = read_time_normalized_forces("Kole/Kole_ER_BigData.xlsx",␣
 ↪n_samples=n_samples)
kam_forces  = read_time_normalized_forces("Kam/Kam_ER_BigData.xlsx",␣
 ↪n_samples=n_samples)

# 2. If both datasets loaded, compute mean & std at each time point
if kole_forces is not None and kam_forces is not None:
    # (num_reps, n_samples) -> mean, std across axis=0 -> shape (n_samples,)
    kole_mean = np.mean(kole_forces, axis=0)
    kole_std  = np.std(kole_forces, axis=0)

    kam_mean = np.mean(kam_forces, axis=0)
    kam_std  = np.std(kam_forces, axis=0)

    # 3. Create time axis from 0..1
    t = np.linspace(0, 1, n_samples)

    # 4. Plot Mean ± Std for both
    plt.figure("Comparison of Time-Normalized Average Force ± Std")
    plt.clf()

    # Kole: mean (red line), std fill
    plt.plot(t, kole_mean, color='red', label='Kole (Uninjured) Mean Force')
    plt.fill_between(t, kole_mean - kole_std, kole_mean + kole_std,
                     color='red', alpha=0.2, label='Kole ±1 std')

    # Kam: mean (blue line), std fill
    plt.plot(t, kam_mean, color='blue', label='Kam (Injury) Mean Force')
    plt.fill_between(t, kam_mean - kam_std, kam_mean + kam_std,
                     color='blue', alpha=0.2, label='Kam ±1 std')

    plt.xlabel('Normalized Time (0..1)')
    plt.ylabel('Force')
    plt.title('Comparison of Time-Normalized Average Force (Mean ± Std)')
    plt.legend()
    plt.show()
```

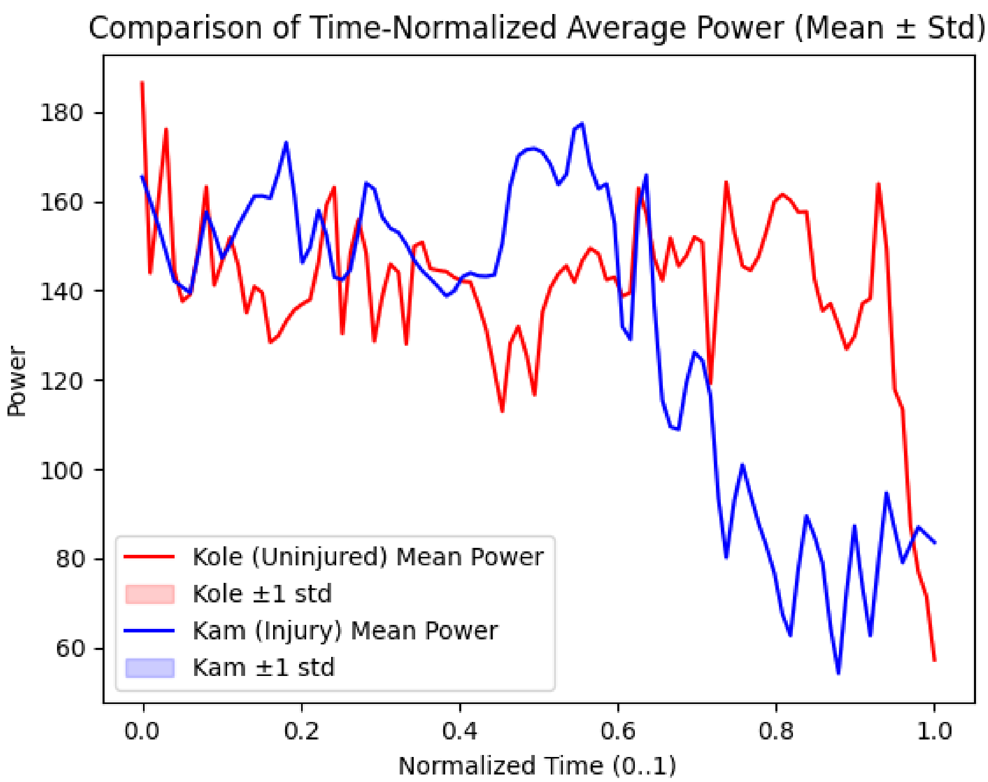


[27]:

```
%matplotlib widget
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.interpolate import interp1d

def time_normalize_power(df, n_samples=100):
    """
    Given a DataFrame `df` with a 'Power' column, returns a 1D array of length␣
 ↪n_samples
    representing the time-normalized power data from t=0..1.
    """
    if 'Power' not in df.columns:
        return None

    n_points = len(df)
    if n_points < 2:
        return None  # Not enough data to interpolate

    # Original time parameter from 0..1
    t_original = np.linspace(0, 1, n_points)
```

```
    # Interpolation function for Power
    f_power = interp1d(t_original, df['Power'], kind='linear')

    # Resample to n_samples points in [0, 1]
    t_resampled = np.linspace(0, 1, n_samples)
    power_resampled = f_power(t_resampled)  # shape: (n_samples,)

    return power_resampled

def read_time_normalized_powers(file_path, n_samples=100):
    """
    Reads all sheets from the given Excel file, time-normalizes the 'Power'␣
↪column
    in each sheet to n_samples points, and returns a 2D array of shape␣
↪(num_reps, n_samples).
    """
    # Read all sheets as a dict of {sheet_name: DataFrame}
    sheets = pd.read_excel(file_path, engine="calamine", sheet_name=None)

    all_powers = []
    for sheet_name, df in sheets.items():
        # Time-normalize the Power data in this sheet
        power_array = time_normalize_power(df, n_samples=n_samples)
        if power_array is not None:
            all_powers.append(power_array)
        else:
            print(f"Skipping sheet '{sheet_name}' (no  column or insufficient␣
↪data).")

    if len(all_powers) == 0:
        print(f"No valid  data found in {file_path}.")
        return None

    # Convert list of 1D arrays into a 2D array: (num_reps, n_samples)
    return np.array(all_powers)

# -------------------------------
# Main: Compute and Plot Mean ± Std
# -------------------------------

# 1. Read time-normalized powers for each file
n_samples = 100
kole_powers = read_time_normalized_powers("Kole/Kole_ER_Analysis.xlsx",␣
↪n_samples=n_samples)
kam_powers  = read_time_normalized_powers("Kam/Kam_ER_Analysis.xlsx",␣
↪n_samples=n_samples)
```

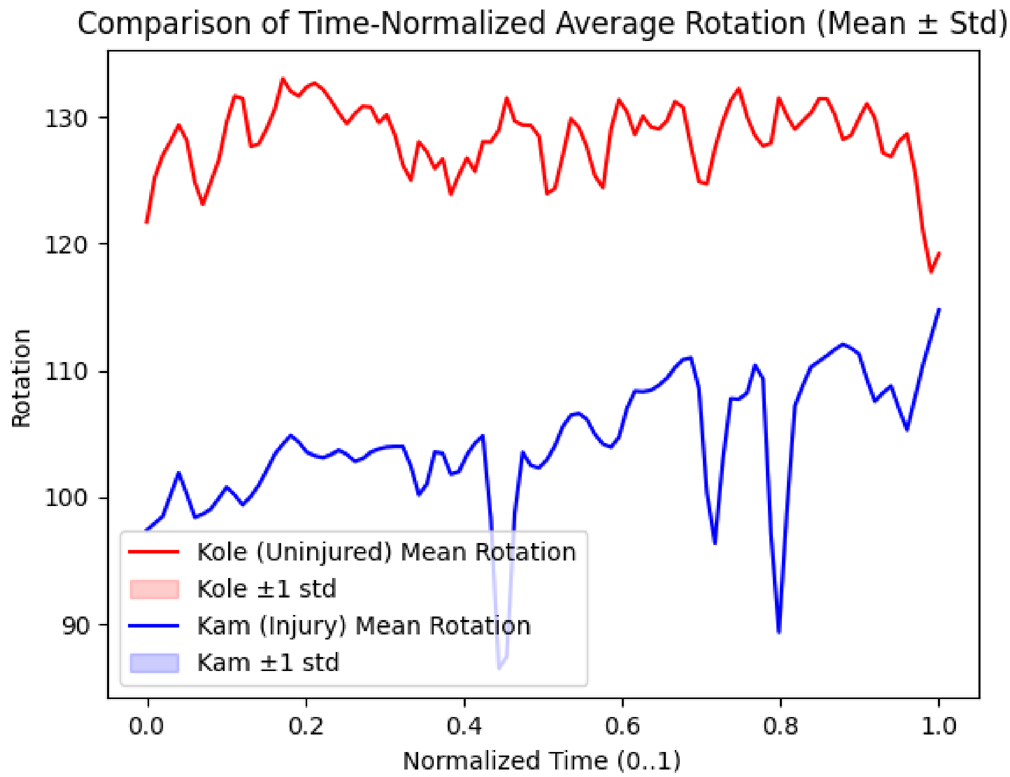
```python
# 2. If both datasets loaded, compute mean & std at each time point
if kole_powers is not None and kam_powers is not None:
    # (num_reps, n_samples) -> mean, std across axis=0 -> shape (n_samples,)
    kole_mean = np.mean(kole_powers, axis=0)
    kole_std  = np.std(kole_powers, axis=0)

    kam_mean = np.mean(kam_powers, axis=0)
    kam_std  = np.std(kam_powers, axis=0)

    # 3. Create time axis from 0..1
    t = np.linspace(0, 1, n_samples)

    # 4. Plot Mean ± Std for both
    plt.figure("Comparison of Time-Normalized Average Power ± Std")
    plt.clf()

    # Kole: mean (red line), std fill
    plt.plot(t, kole_mean, color='red', label='Kole (Uninjured) Mean Power')
    plt.fill_between(t, kole_mean - kole_std, kole_mean + kole_std,
                     color='red', alpha=0.2, label='Kole ±1 std')

    # Kam: mean (blue line), std fill
    plt.plot(t, kam_mean, color='blue', label='Kam (Injury) Mean Power')
    plt.fill_between(t, kam_mean - kam_std, kam_mean + kam_std,
                     color='blue', alpha=0.2, label='Kam ±1 std')

    plt.xlabel('Normalized Time (0..1)')
    plt.ylabel('Power')
    plt.title('Comparison of Time-Normalized Average Power (Mean ± Std)')
    plt.legend()
    plt.show()
```



[28]:
```
%matplotlib widget
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from scipy.interpolate import interp1d

def time_normalize_rotation(df, n_samples=100):
    """
    Given a DataFrame `df` with a 'Rotation' column, returns a 1D array of␣
 ↪length n_samples
    representing the time-normalized rotation data from t=0..1.
    """
    if 'Rotation' not in df.columns:
        return None

    n_points = len(df)
    if n_points < 2:
        return None  # Not enough data to interpolate

    # Original time parameter from 0..1
    t_original = np.linspace(0, 1, n_points)
```

```
    # Interpolation function for Rotation
    f_rotation = interp1d(t_original, df['Rotation'], kind='linear')

    # Resample to n_samples points in [0, 1]
    t_resampled = np.linspace(0, 1, n_samples)
    rotation_resampled = f_rotation(t_resampled)  # shape: (n_samples,)

    return rotation_resampled

def read_time_normalized_rotations(file_path, n_samples=100):
    """
    Reads all sheets from the given Excel file, time-normalizes the 'Rotation'␣
↪column
    in each sheet to n_samples points, and returns a 2D array of shape␣
↪(num_reps, n_samples).
    """
    # Read all sheets as a dict of {sheet_name: DataFrame}
    sheets = pd.read_excel(file_path, engine="calamine", sheet_name=None)

    all_rotations = []
    for sheet_name, df in sheets.items():
        # Time-normalize the Rotation data in this sheet
        rotation_array = time_normalize_rotation(df, n_samples=n_samples)
        if rotation_array is not None:
            all_rotations.append(rotation_array)
        else:
            print(f"Skipping sheet '{sheet_name}' (no  column or insufficient␣
↪data).")

    if len(all_rotations) == 0:
        print(f"No valid  data found in {file_path}.")
        return None

    # Convert list of 1D arrays into a 2D array: (num_reps, n_samples)
    return np.array(all_rotations)

# -------------------------------
# Main: Compute and Plot Mean ± Std
# -------------------------------

# 1. Read time-normalized rotations for each file
n_samples = 100
kole_rotations = read_time_normalized_rotations("Kole/Kole_ER_Analysis.xlsx",␣
↪n_samples=n_samples)
kam_rotations  = read_time_normalized_rotations("Kam/Kam_ER_Analysis.xlsx",␣
↪n_samples=n_samples)
```

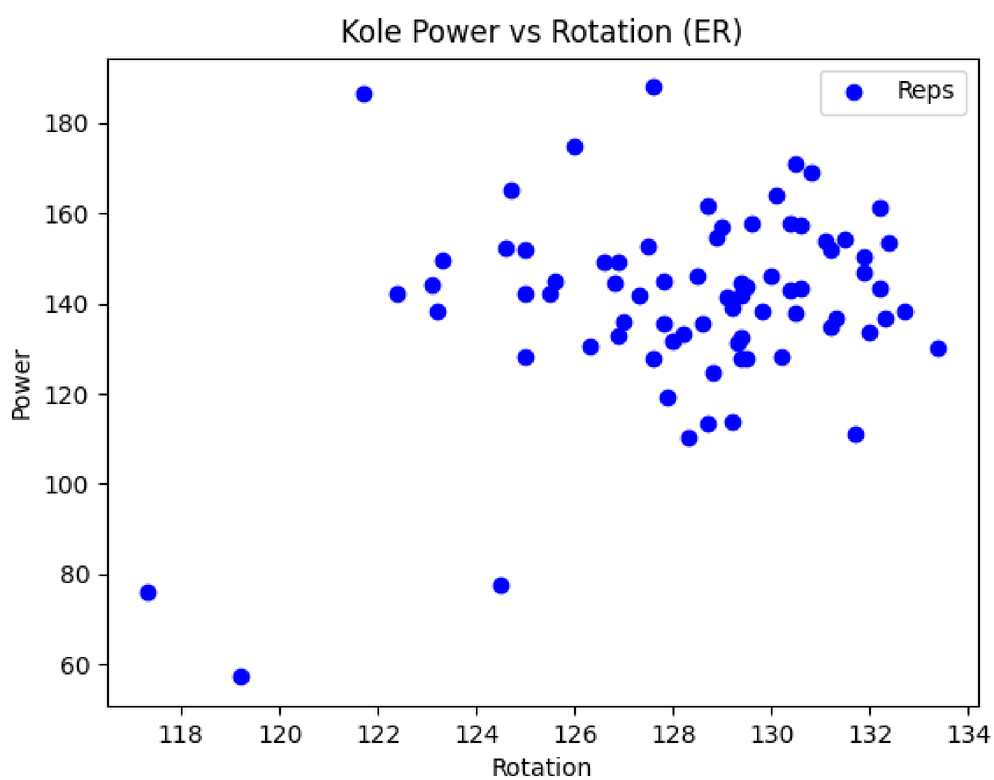
```python
# 2. If both datasets loaded, compute mean & std at each time point
if kole_rotations is not None and kam_rotations is not None:
    # (num_reps, n_samples) -> mean, std across axis=0 -> shape (n_samples,)
    kole_mean = np.mean(kole_rotations, axis=0)
    kole_std  = np.std(kole_rotations, axis=0)

    kam_mean = np.mean(kam_rotations, axis=0)
    kam_std  = np.std(kam_rotations, axis=0)

    # 3. Create time axis from 0..1
    t = np.linspace(0, 1, n_samples)

    # 4. Plot Mean ± Std for both
    plt.figure("Comparison of Time-Normalized Average Rotation ± Std")
    plt.clf()

    # Kole: mean (red line), std fill
    plt.plot(t, kole_mean, color='red', label='Kole (Uninjured) Mean Rotation')
    plt.fill_between(t, kole_mean - kole_std, kole_mean + kole_std,
                     color='red', alpha=0.2, label='Kole ±1 std')

    # Kam: mean (blue line), std fill
    plt.plot(t, kam_mean, color='blue', label='Kam (Injury) Mean Rotation')
    plt.fill_between(t, kam_mean - kam_std, kam_mean + kam_std,
                     color='blue', alpha=0.2, label='Kam ±1 std')

    plt.xlabel('Normalized Time (0..1)')
    plt.ylabel('Rotation')
    plt.title('Comparison of Time-Normalized Average Rotation (Mean ± Std)')
    plt.legend()
    plt.show()
```

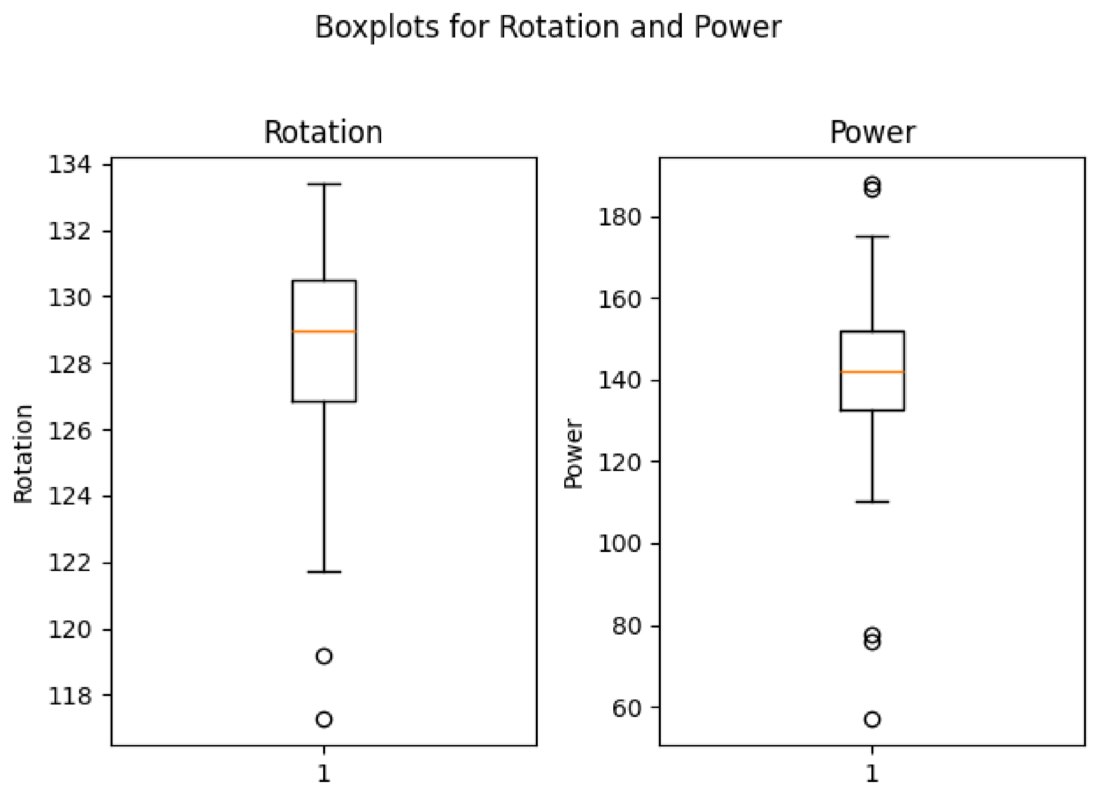


[37]:

```
%matplotlib widget
import pandas as pd
import matplotlib.pyplot as plt

# Read only the first sheet from the Excel file.
df = pd.read_excel("Kole/Kole_ER_Analysis.xlsx", sheet_name=0,␣
 ↪engine="calamine")

# ---------------------------
# Scatter Plot: Power vs Rotation
# ---------------------------
plt.figure("Kole Power vs Rotation")
plt.clf()

plt.scatter(df["Rotation"], df["Power"], color="blue", label="Reps")
plt.xlabel("Rotation")
plt.ylabel("Power")
plt.title("Kole Power vs Rotation (ER)")
plt.legend()
plt.show()
```

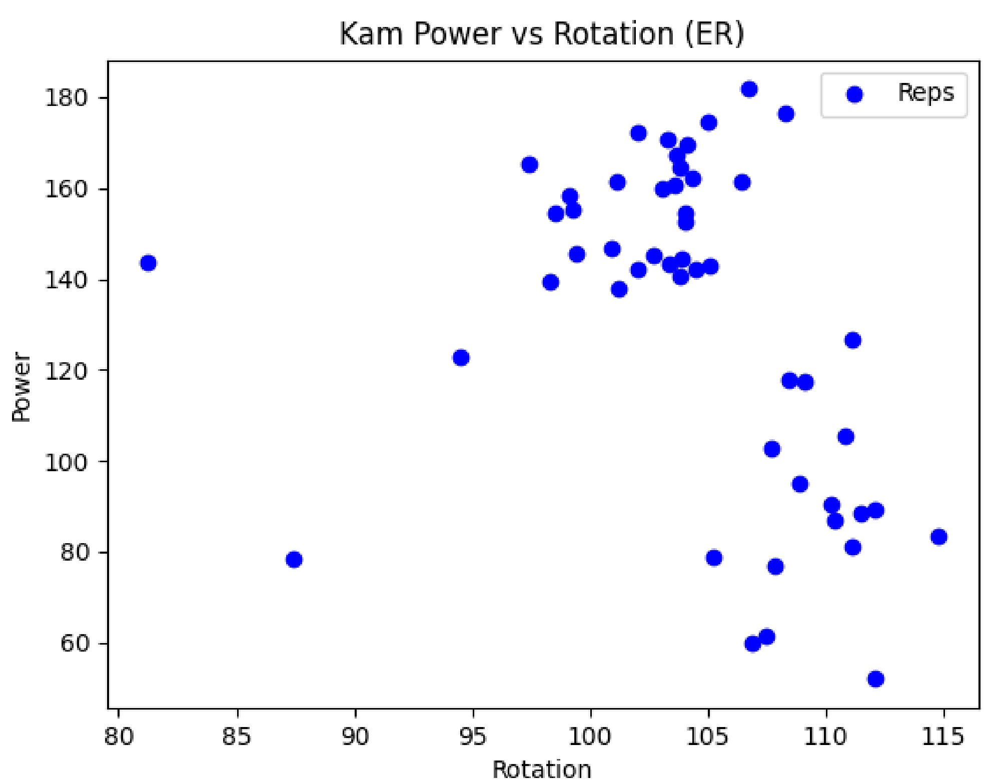
```
# ----------------------------
# Boxplots: One for Rotation, One for Power
# ----------------------------
plt.figure("Boxplots for Rotation and Power")
plt.clf()

# Create a subplot with two side-by-side plots.
plt.subplot(1, 2, 1)
plt.boxplot(df["Rotation"])
plt.title("Rotation")
plt.ylabel("Rotation")

plt.subplot(1, 2, 2)
plt.boxplot(df["Power"])
plt.title("Power")
plt.ylabel("Power")

plt.suptitle("Boxplots for Rotation and Power")
plt.tight_layout(rect=[0, 0.03, 1, 0.95])
plt.show()
```

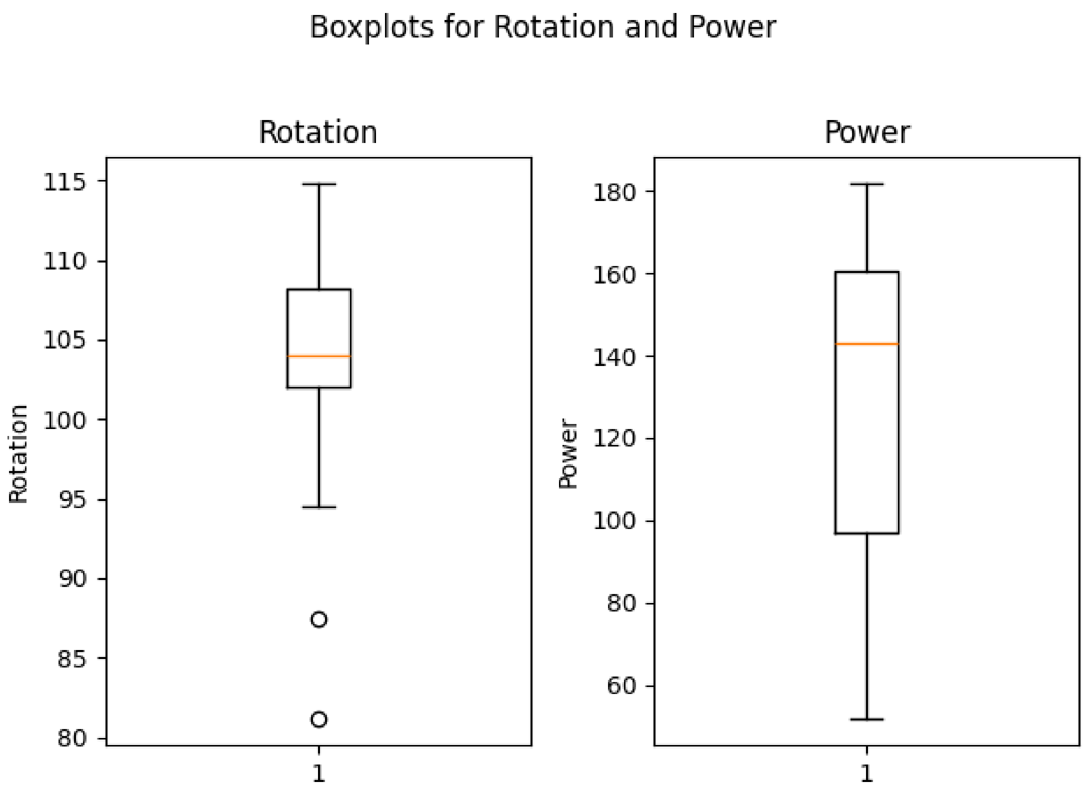




[38]:
```
%matplotlib widget
import pandas as pd
import matplotlib.pyplot as plt

# Read only the first sheet from the Excel file.
df = pd.read_excel("Kam/Kam_ER_Analysis.xlsx", sheet_name=0, engine="calamine")

# ----------------------------
# Scatter Plot: Power vs Rotation
# ----------------------------
plt.figure("Kam Power vs Rotation")
plt.clf()

plt.scatter(df["Rotation"], df["Power"], color="blue", label="Reps")
plt.xlabel("Rotation")
plt.ylabel("Power")
plt.title("Kam Power vs Rotation (ER)")
plt.legend()
plt.show()

# ----------------------------
```

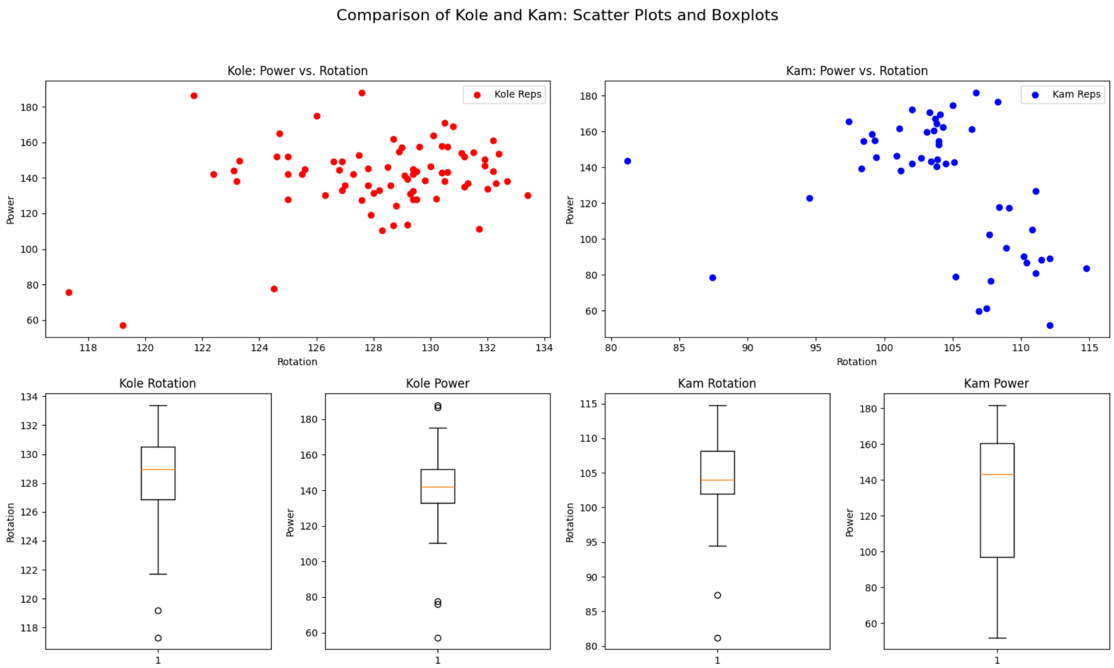
```python
# Boxplots: One for Rotation, One for Power
# ----------------------------
plt.figure("Boxplots for Rotation and Power")
plt.clf()

# Create a subplot with two side-by-side plots.
plt.subplot(1, 2, 1)
plt.boxplot(df["Rotation"])
plt.title("Rotation")
plt.ylabel("Rotation")

plt.subplot(1, 2, 2)
plt.boxplot(df["Power"])
plt.title("Power")
plt.ylabel("Power")

plt.suptitle("Boxplots for Rotation and Power")
plt.tight_layout(rect=[0, 0.03, 1, 0.95])
plt.show()
```





[39]:
```
%matplotlib widget
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.gridspec as gridspec

# Read the first sheet from each file.
kole_df = pd.read_excel("Kole/Kole_ER_Analysis.xlsx", sheet_name=0,␣
 ↪engine="calamine")
kam_df  = pd.read_excel("Kam/Kam_ER_Analysis.xlsx", sheet_name=0,␣
 ↪engine="calamine")

# Create a figure with a GridSpec layout.
fig = plt.figure(figsize=(16, 10))
gs = gridspec.GridSpec(2, 4, height_ratios=[1, 1])

# --- Top Row: Scatter Plots ---

# Left scatter plot: Kole
ax1 = fig.add_subplot(gs[0, 0:2])
```

```
ax1.scatter(kole_df["Rotation"], kole_df["Power"], color="red", label="Kole␣
↪Reps")
ax1.set_title("Kole: Power vs. Rotation")
ax1.set_xlabel("Rotation")
ax1.set_ylabel("Power")
ax1.legend()

# Right scatter plot: Kam
ax2 = fig.add_subplot(gs[0, 2:4])
ax2.scatter(kam_df["Rotation"], kam_df["Power"], color="blue", label="Kam Reps")
ax2.set_title("Kam: Power vs. Rotation")
ax2.set_xlabel("Rotation")
ax2.set_ylabel("Power")
ax2.legend()

# --- Bottom Row: Boxplots ---

# Boxplot for Kole Rotation
ax3 = fig.add_subplot(gs[1, 0])
ax3.boxplot(kole_df["Rotation"])
ax3.set_title("Kole Rotation")
ax3.set_ylabel("Rotation")

# Boxplot for Kole Power
ax4 = fig.add_subplot(gs[1, 1])
ax4.boxplot(kole_df["Power"])
ax4.set_title("Kole Power")
ax4.set_ylabel("Power")

# Boxplot for Kam Rotation
ax5 = fig.add_subplot(gs[1, 2])
ax5.boxplot(kam_df["Rotation"])
ax5.set_title("Kam Rotation")
ax5.set_ylabel("Rotation")

# Boxplot for Kam Power
ax6 = fig.add_subplot(gs[1, 3])
ax6.boxplot(kam_df["Power"])
ax6.set_title("Kam Power")
ax6.set_ylabel("Power")

fig.suptitle("Comparison of Kole and Kam: Scatter Plots and Boxplots",␣
↪fontsize=16)
plt.tight_layout(rect=[0, 0.03, 1, 0.95])
plt.show()
```


Comparison of Kole and Kam: Scatter Plots and Boxplots
Kole: Power vs. Rotation
Kole Reps
Kam: Power vs. Rotation
Kam Reps
Power
Rotation
Kole Rotation
Kole Power
Kam Rotation
Kam Power

[ ]: