2.5.5

Shreyas Goud Burra - EE25BTECH11051

September 6, 2025

Question

Write the projection of the vector $(\mathbf{b}+\mathbf{c})$ on the vector $\mathbf{a}$, where $\mathbf{a} = 2\hat{i} - 2\hat{j} + \hat{k}$, $\mathbf{b} = \hat{i} + 2\hat{j} - 2\hat{k}$, and $\mathbf{c} = 2\hat{i} - \hat{j} + 4\hat{k}$.

Given Information

Let the vectors be represented as **A**, **B**, and **C** respectively. Given by

$$\mathbf{A} = \begin{pmatrix} 2 \\ -2 \\ 1 \end{pmatrix}, \mathbf{B} = \begin{pmatrix} 1 \\ 2 \\ -2 \end{pmatrix}, \mathbf{C} = \begin{pmatrix} 2 \\ -1 \\ 4 \end{pmatrix} \tag{1}$$

Solution

Mathematically, the projection of the vector $\mathbf{B}+\mathbf{C}$ on the vector $\mathbf{A}$ is given by some vector $\mathbf{D}$,

$$\mathbf{D} = k\mathbf{A}, \text{ such that } ((\mathbf{B}+\mathbf{C}) - \mathbf{D})^{\mathsf{T}}\mathbf{D} = 0 \tag{2}$$

Continuation

yielding,

$$((\mathbf{B}+\mathbf{C})-k\mathbf{A})^{\mathsf{T}}\mathbf{A}=0 \tag{3}$$

or,

$$k=\frac{(\mathbf{B}+\mathbf{C})^{\mathsf{T}}\mathbf{A}}{\|\mathbf{A}\|^2} \implies \mathbf{D}=\frac{(\mathbf{B}+\mathbf{C})^{\mathsf{T}}\mathbf{A}}{\|\mathbf{A}\|^2}\mathbf{A} \tag{4}$$

Continuation

On substituting the values,

$$\mathbf{D} = \frac{\left(\begin{pmatrix} 1 \\ 2 \\ -2 \end{pmatrix} + \begin{pmatrix} 2 \\ -1 \\ 4 \end{pmatrix}\right)^{\mathsf{T}} \begin{pmatrix} 2 \\ -2 \\ 1 \end{pmatrix}}{\left\| \begin{pmatrix} 2 \\ -2 \\ 1 \end{pmatrix} \right\|^2} \begin{pmatrix} 2 \\ -2 \\ 1 \end{pmatrix} \tag{5}$$

Final Answer

On calculation, this gives us,

$$\mathbf{D} = \begin{pmatrix} 4/3 \\ -4/3 \\ 2/3 \end{pmatrix} \tag{6}$$

C code

```c
#include <stddef.h>
#include<math.h>

void project(double* result, const double* arr2, const double*
    arr3, int length) {
    float dot_product = 0.0f;
    float magnitude_squared = 0.0f;

    for (int i = 0; i < length; i++) {
        dot_product += arr2[i] * arr3[i];
    }


    for (int i = 0; i < length; i++) {
        magnitude_squared += arr3[i] * arr3[i];
    }
```

C code

```
    if (magnitude_squared == 0.0f) {
        for (int i = 0; i < length; i++) {
            result[i] = 0.0f;
        }
        return;
    }


    const float scalar = dot_product / magnitude_squared;
```

C code

```
    for (int i = 0; i < length; i++) {
        result[i] = scalar * arr3[i];
    }

    for(int i=0; i<length; i++){
        result[i] = floor(result[i] * 100) / 100;
    }
}
```

Python code

```
import numpy as np
import matplotlib.pyplot as plt
import ctypes
import os
import sys

project_lib = ctypes.CDLL('./project.so')
project_lib.project.argtypes = [
        ctypes.POINTER(ctypes.c_double),
        ctypes.POINTER(ctypes.c_double),
        ctypes.POINTER(ctypes.c_double),
        ctypes.c_int
]

project_lib.project.restype = ctypes.c_double
```

C code

```
#E = B+C

A=np.array([2, -2, 1], dtype=np.float64)
B=np.array([1, 2, -2], dtype=np.float64)
C=np.array([2, -1, 4], dtype=np.float64)
D=np.zeros(3, dtype=np.float64)
E=B+C

m=len(A)
```

Python code

```
project=project_lib.project(
        D.ctypes.data_as(ctypes.POINTER(ctypes.c_double)),
        E.ctypes.data_as(ctypes.POINTER(ctypes.c_double)),
        A.ctypes.data_as(ctypes.POINTER(ctypes.c_double)),
        m
)


fig=plt.figure()
ax=fig.add_subplot(111, projection='3d')

ax.quiver(0, 0, 0, E[0], E[1], E[2], color='b',
    arrow_length_ratio=0.1)
ax.quiver(0, 0, 0, A[0], A[1], A[2], color='r',
    arrow_length_ratio=0.1)
ax.quiver(0, 0, 0, D[0], D[1], D[2], color='g',
    arrow_length_ratio=0.2)
```

Python code

```
label = f'({A[0]}, {A[1]}, {A[2]})'
ax.text(A[0], A[1], A[2], s=label, color='b', fontsize=10)

label = f'({E[0]}, {E[1]}, {E[2]})'
ax.text(E[0], E[1], E[2], s=label, color='b', fontsize=10)

label = f'({D[0]}, {D[1]}, {D[2]})'
ax.text(D[0], D[1], D[2], s=label, color='b', fontsize=10)
```

C code

```
ax.scatter(A[0], A[1], A[2], color='r', s=50)
ax.scatter(E[0], E[1], E[2], color='b', s=50)
ax.scatter(D[0], D[1], D[2], color='g', s=50)

ax.set_xlim([0, 4])
ax.set_ylim([-4, 4])
ax.set_zlim([-4, 4])
```

Python code

```
ax.set_xlabel('X-axis')
ax.set_ylabel('Y-axis')
ax.set_zlabel('Z-axis')

plt.title('Vector Projection')

plt.savefig('/home/shreyas/GVV_Assignments/matgeo/2.5.5/figs/fig1
    .png')

plt.show()
```

Plot

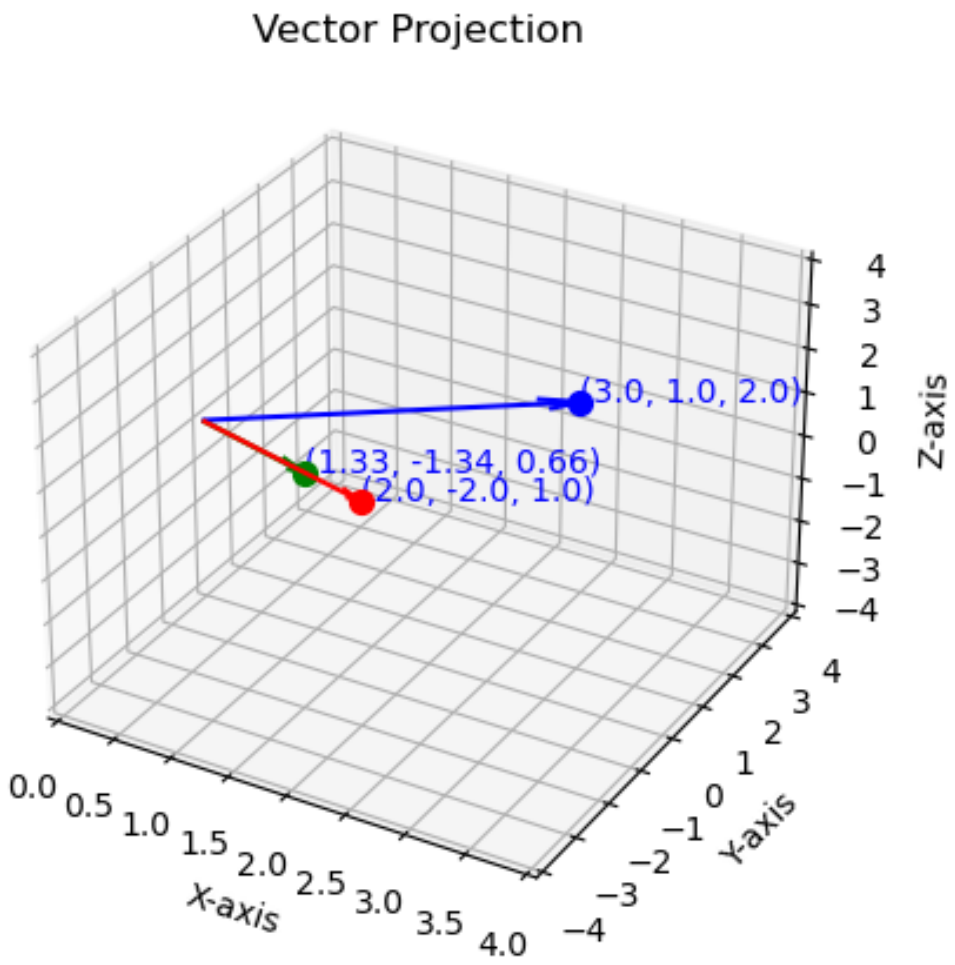

Figure: 3D Plot