4.2.15

BEERAM MADHURI - EE25BTECH11012

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Question

Find the direction and normal vectors of $y = 2x$.

given data

Line equation is $y = 2x$

finding direction and normal vectors of $y = 2x$

The line can be written as:

$$-2x + 1y = 0 \tag{1}$$

This equation can be expressed in terms of matrices as:

$$\mathbf{n}^\top \mathbf{x} = c \tag{2}$$

$$\mathbf{n}^\top = \begin{pmatrix} -2 & 1 \end{pmatrix} \tag{3}$$

$$\mathbf{x} = \begin{pmatrix} x \\ y \end{pmatrix} \tag{4}$$

$$c = 0 \tag{5}$$

where **n** is normal vector of the given line.
The direction vector is:

$$\mathbf{m} = \begin{pmatrix} 1 \\ 2 \end{pmatrix}. \tag{6}$$

This is true because, if the direction vector is represented as

$$\mathbf{m} = \begin{pmatrix} 1 \\ m \end{pmatrix} \tag{7}$$

then the normal vector can be expressed as

$$\mathbf{n} = \begin{pmatrix} -m \\ 1 \end{pmatrix} \tag{8}$$

$$\mathbf{n}^\top \mathbf{m} = 0 \tag{9}$$

$$\begin{pmatrix} -2 & 1 \end{pmatrix} \begin{pmatrix} 1 \\ 2 \end{pmatrix} = 0 \tag{10}$$

Hence, normal vector $\mathbf{n} = \begin{pmatrix} -2 \\ 1 \end{pmatrix}$ and direction vector $\mathbf{m} = \begin{pmatrix} 1 \\ 2 \end{pmatrix}$.

Python Code

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

# --- 1. Vector Calculation ---
# The equation of the line is y = 2x.
# The standard form is Ax + By + C = 0, which is 2x - y = 0.
A = 2
B = -1

# The normal vector is <A, B>. It's perpendicular to the line.
normal_vector = np.array([A, B])
```

Python Code

```python
# The direction vector is <-B, A>. It's parallel to the line.
direction_vector = np.array([-B, A])

print(f"Line Equation: y = 2x")
print("-" * 25)
print(f"Direction Vector: {tuple(direction_vector)}")
print(f"Normal Vector: {tuple(normal_vector)}")
```

Python Code

```python
# Create a figure and a set of subplots
fig, ax = plt.subplots(figsize=(8, 8))

# Generate x values for our line
x_vals = np.linspace(-2.5, 2.5, 100)
# Calculate the corresponding y values for the line y = 2x
y_vals = 2 * x_vals

# Plot the main line
ax.plot(x_vals, y_vals, label='Line: y = 2x', color='blue',
    zorder=1)
```

Python Code

```python
# Plot the vectors as arrows starting from the origin (0,0)
# The 'quiver' function is used to plot arrows.

# Plot the Direction Vector (green)
ax.quiver(0, 0, direction_vector[0], direction_vector[1],
          angles='xy', scale_units='xy', scale=1,
          color='green', label=f'Direction Vector: {tuple(
              direction_vector)}', zorder=2)

# Plot the Normal Vector (red)
ax.quiver(0, 0, normal_vector[0], normal_vector[1],
          angles='xy', scale_units='xy', scale=1,
          color='red', label=f'Normal Vector: {tuple(normal_vector
              )}', zorder=2)
```

Python Code

```python
# Set the aspect ratio of the plot to be equal, so 90-degree angles look correct
ax.set_aspect('equal')

# Set the limits for the x and y axes
ax.set_xlim(-4, 4)
ax.set_ylim(-4, 4)

# Move the x and y axes to the center of the plot
ax.spines['left'].set_position('zero')
ax.spines['bottom'].set_position('zero')
ax.spines['right'].set_color('none')
ax.spines['top'].set_color('none')
```

Python Code

```python
# Add a grid for better readability
ax.grid(True, linestyle='--')

# Add a title and a legend
ax.set_title("Line y=2x with its Direction and Normal Vectors",
    fontsize=14)
ax.legend(loc='upper left')

# Display the plot
plt.show()
```

C Code

```c
#include <stdio.h>
// A simple structure to represent a 2D vector
typedef struct {
    float x;
    float y;
} Vector2D;
int main() {
    // Equation of the line: y = 2x
    // General form: 2x - 1y + 0 = 0
    // So, A = 2 and B = -1
```

C Code

```c
    float A = 2.0f;
    float B = -1.0f;
    // Declare vectors
    Vector2D normal_vector;
    Vector2D direction_vector;
    // For a line Ax + By + C = 0:
    // A normal vector is given by n = (A, B)
    normal_vector.x = A;
    normal_vector.y = B;
```

C Code

```c
    // A direction vector is perpendicular to the normal vector.
    // It can be found as d = (-B, A) or (B, -A)
    direction_vector.x = -B;
    direction_vector.y = A;
    printf("For the line y = 2x (or 2x - y = 0):\n");
    printf("----------------------------------------\n");
    printf("Calculated Normal Vector (A, B) : <%.1f, %.1f>\n",
        normal_vector.x, normal_vector.y);
    printf("Calculated Direction Vector (-B, A): <%.1f, %.1f>\n",
         direction_vector.x, direction_vector.y);
    return 0;
}
```

Python and C Code

```
import ctypes
import platform
# --- 1. Define a Python class that mirrors the C struct ---
class Vector2D(ctypes.Structure):
    fields = [("x", ctypes.c_float),
               ("y", ctypes.c_float)]
```

Python and C Code

```python
# --- 2. Load the shared library ---
if platform.system() == "Windows":
    lib_path = "./libline.dll"
else:
    lib_path = "./libline.so"

try:
    lib = ctypes.CDLL(lib_path)
except OSError as e:
    print(f"Error loading library: {e}")
    print("Have you compiled line_vectors.c?")
    exit()
```

Python and C Code

```
# --- 3. Define the function signature ---
lib.get_line_vectors.argtypes = [
    ctypes.c_float, # A
    ctypes.c_float, # B
    ctypes.POINTER(Vector2D), # normal_out (output)
    ctypes.POINTER(Vector2D) # direction_out (output)
]
lib.get_line_vectors.restype = None
```

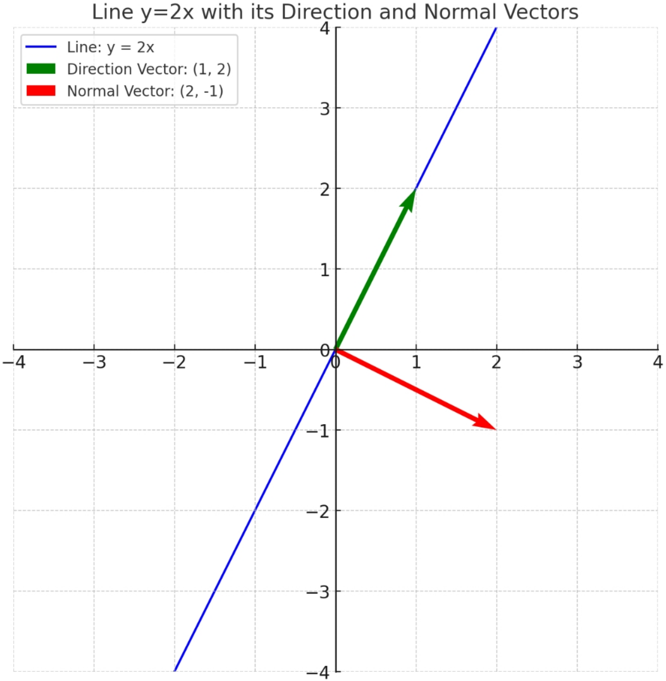
Python and C Code

```
# --- 4. Prepare data and call the C function ---
# Hardcoded input values for the line 2x - y = 0
A = 2.0
B = -1.0

# Create empty instances of our Vector2D class for the output
normal_vector = Vector2D()
direction_vector = Vector2D()
```

Python and C Code

```python
# Call the C function with the hardcoded inputs
lib.get_line_vectors(A, B, ctypes.byref(normal_vector), ctypes.byref(direction_vector))
# --- 5. Print the results ---
print("For the line y = 2x (or 2x - y = 0):")
print("----------------------------------------")
print(f"Calculated Normal Vector (A, B) : <{normal_vector.x:.1f}, {normal_vector.y:.1f}>")
print(f"Calculated Direction Vector (-B, A): <{direction_vector.x:.1f}, {direction_vector.y:.1f}>")
```


Line y=2x with its Direction and Normal Vectors
Line: y = 2x
🟩 Direction Vector: (1, 2)
🟥 Normal Vector: (2, -1)
−4
−3
−2
−1
0
1
2
3
4
4
3
2
1
0
−1
−2
−3
−4