실습 보고서

[실습번호: 04]

[실습제목: 5 장 행렬식/determinant]

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가. 구글 코랩 이용하여 inverse matrix 계산하기

04 프로그래밍 실습

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```
import numpy as np

# 행렬 A를 출력하는 함수
def pprint(msg, A):
  print("---", msg, "---");
  (n, m) = A.shape
  for i in range(0, n):
    line = ""
    for j in range(0, m):
      line += "{0:.2f}".format(A[i,j]) + "\t"
    print(line)
  print("")

A = np.array([[1., 2.], [3., 4.]])
pprint("A", A)

Ainv1 = np.linalg.matrix_power(A, -1)  # matrix_power()를 사용한 역행렬 A^-1 계산
pprint("linalg.matrix_power(A, -1) => Ainv1", Ainv1)

Ainv2 = np.linalg.inv(A)               # inv()를 사용한 역행렬 A^-1 계산
pprint("np.linalg.inv(A) => Ainv2", Ainv2)

pprint("A*Ainv1", np.matmul(A, Ainv2))  # 행렬 A와 역행렬 A^-1의 곱
pprint("A*Ainv2", np.matmul(A, Ainv2))  # 행렬 A와 역행렬 A^-1의 곱

B = np.random.rand(3,3)                # 난수를 이용한 3x3행렬 B 생성
pprint("B =", B)
Binv = np.linalg.inv(B)                # 역행렬 B^-1 계산
pprint("Binv =", Binv)
pprint("B*Binv =", np.matmul(B, Binv)) # 행렬 B와 역행렬 B^-1의 곱

# CX = D의 해 계산
C = np.array([[5, 3, 2, 1], [6, 2, 4, 5], [7, 4, 1, 3], [4, 3, 5, 2]])
D = np.array([[4], [2], [5], [1]])
x = np.matmul(np.linalg.inv(C), D)
pprint("x", x)                         # 해 x 출력
pprint("C*x", np.matmul(C, x))         # C*x의 결과가 D와 같은지 확인
```

```
--- A ---
1.00    2.00
3.00    4.00

--- linalg.matrix_power(A, -1) => Ainv1 ---
-2.00   1.00
1.50    -0.50

--- np.linalg.inv(A) => Ainv2 ---
-2.00   1.00
1.50    -0.50

--- A*Ainv1 ---
1.00    0.00
0.00    1.00

--- A*Ainv2 ---
1.00    0.00
0.00    1.00

--- B = ---
0.64    0.10    0.51
0.66    0.36    0.69
0.08    0.27    0.31

--- Binv = ---
-5.96   8.35    -8.76
-11.49  12.08   -7.94
11.68   -12.83  12.50

--- B*Binv = ---
1.00    0.00    -0.00
-0.00   1.00    -0.00
0.00    -0.00   1.00

--- x ---
1.31
-0.38
-0.31
-0.77

--- C*x ---
4.00
2.00
5.00
1.00
```

4장 연습문제 7번

```python
import numpy as np

# 행렬 출력 함수
def pprint(msg, A):
  print("---", msg, "---")
  (n, m) = A.shape
  for i in range(n):
    line = ""
    for j in range(m):
      line += "{0:.2f}".format(A[i,j]) + "\t"
    print(line)
  print("")

# 역행렬 계산 함수 (행렬식 검사 포함)
def safe_inv(A, name):
  det = np.linalg.det(A)
  if np.isclose(det, 0):
    print(f"--- {name} ---")
    print("행렬식 0, 역행렬 없음 (특이 행렬)\n")
    return None
  else:
    Ainv = np.linalg.inv(A)
    pprint(f"np.linalg.inv({name}) => {name}inv", Ainv)
    return Ainv

A = np.array([[8., 6.], [5., 4.]])
pprint("A", A)
Ainv_A = safe_inv(A, "A")

B = np.array([[3., 2.], [8., 5.]])
pprint("B", B)
Ainv_B = safe_inv(B, "B")

C = np.array([[7., 3.], [-6., -3.]])
pprint("C", C)
Ainv_C = safe_inv(C, "C")

D = np.array([[2., -4.], [4., -6.]])
pprint("D", D)
Ainv_D = safe_inv(D, "D")
```

```
--- A ---
8.00    6.00
5.00    4.00

--- np.linalg.inv(A) => Ainv ---
2.00    -3.00
-2.50   4.00

--- B ---
3.00    2.00
8.00    5.00

--- np.linalg.inv(B) => Binv ---
-5.00   2.00
8.00    -3.00

--- C ---
7.00    3.00
-6.00   -3.00

--- np.linalg.inv(C) => Cinv ---
1.00    1.00
-2.00   -2.33

--- D ---
2.00    -4.00
4.00    -6.00

--- np.linalg.inv(D) => Dinv ---
-1.50   1.00
-1.00   0.50
```

4장 연습문제 8번

```python
import numpy as np

# 행렬 출력 함수
def pprint(msg, A):
  print("---", msg, "---")
  (n, m) = A.shape
  for i in range(n):
    line = ""
    for j in range(m):
      line += "{0:.2f}".format(A[i,j]) + "\t"
    print(line)
  print("")

# 역행렬 계산 함수 (행렬식 검사 포함)
def safe_inv(A, name):
  det = np.linalg.det(A)
  if np.isclose(det, 0):
    print(f"--- {name} ---")
    print("행렬식 0, 역행렬 없음 (특이 행렬)\n")
    return None
  else:
    Ainv = np.linalg.inv(A)
    pprint(f"np.linalg.inv({name}) => {name}inv", Ainv)
    return Ainv

A = np.array([[-1., -2.], [-3., -4.]])
pprint("A", A)
Ainv_A = safe_inv(A, "A")

B = np.array([[3., 4.], [1., 2.]])
pprint("B", B)
Ainv_B = safe_inv(B, "B")

C = np.array([[1., 0., 5.], [1., 1., 1.], [0., 1., -4.]])
pprint("C", C)
Ainv_C = safe_inv(C, "C")

D = np.array([[0., 1., 2.], [1., 0., 3.], [4., -3., 8.]])
pprint("D", D)
Ainv_D = safe_inv(D, "D")
```

```
--- A ---
-1.00   -2.00
-3.00   -4.00

--- np.linalg.inv(A) => Ainv ---
2.00    -1.00
-1.50   0.50

--- B ---
3.00    4.00
1.00    2.00

--- np.linalg.inv(B) => Binv ---
1.00    -2.00
-0.50   1.50

--- C ---
1.00    0.00    5.00
1.00    1.00    1.00
0.00    1.00    -4.00

--- C ---
행렬식 0, 역행렬 없음 (특이 행렬)

--- D ---
0.00    1.00    2.00
1.00    0.00    3.00
4.00    -3.00   8.00

--- np.linalg.inv(D) => Dinv ---
-4.50   7.00    -1.50
-2.00   4.00    -1.00
1.50    -2.00   0.50
```

나. 5 장 연습문제 풀기

(1) 복습하기

Determinant 정의 5-1

행렬식(determinant)은 정방행렬 A를 실숫값으로 대응시키는 함수로, det(A) 또는 |A|로 표기한다.
행렬식은 역행렬이 존재하지 않으면 0, 그렇지 않으면 0이 아닌 값을 갖는다.

Minor determinant 정의 5-3

행렬 A에서 성분 a_{ij}가 있는 i행과 j열을 제거한 행렬의 행렬식을 A_{ij}로 표현하고,
이를 a_{ij}의 소행렬식(minor determinant)이라 한다.

Cofactor 정의 5-4

행렬식을 계산할 때 사용되는 a_{ij}의 소행렬식 A_{ij}와 $(-1)^{i+j}$을 곱한 것을
a_{ij}의 여인수(cofactor)라 하고 C_{ij}로 나타낸다. $C_{ij} = (-1)^{i+j} A_{ij}$

2. (a) $|A| = 2\cdot5 - 1\cdot4 = 10-4 = 6$

$\therefore |A| = 6$

(b) $|B| = 4\cdot7 - 3\cdot1 = 28-3 = 25$

$\therefore |B| = 25$

---

3. (a) $C = \begin{pmatrix} 5 & 2 & 3 \\ 3 & -1 & 1 \\ 6 & 4 & 2 \end{pmatrix} \begin{matrix} 5 & 2 \\ 3 & -1 \\ 6 & 4 \end{matrix}$

$|C| = (5\cdot(-1)\cdot2) + (2\cdot1\cdot6) + (3\cdot3\cdot4) - (3\cdot(-1)\cdot6) - (5\cdot1\cdot4) - (2\cdot3\cdot2)$

$= \underbrace{-10+12}_{2}\underbrace{+36}_{38}\underbrace{+18}_{56}\underbrace{-20}_{36}-12 = 24 \qquad \therefore |C| = 24$

(b) $D = \begin{pmatrix} 3 & 2 & 3 \\ 6 & 1 & 2 \\ 1 & 2 & 5 \end{pmatrix} \begin{matrix} 3 & 2 \\ 6 & 1 \\ 1 & 2 \end{matrix}$

$|D| = (3\cdot1\cdot5) + (2\cdot2\cdot1) + (3\cdot6\cdot2) - (3\cdot1\cdot1) - (3\cdot2\cdot2) - (2\cdot6\cdot5)$

$= \underbrace{15+4}_{19}\underbrace{+36}_{55}\underbrace{-3}_{52}\underbrace{-12}_{40}-60 = -20 \qquad \therefore |D| = -20$

---

5. (a) $A_{11} = \begin{pmatrix} 2 & 1 \\ 4 & 5 \end{pmatrix} = (-1)^{1+1}(2\cdot5)-(1\cdot4) = 10-4 = 6 \qquad \therefore |A_{11}| = 6$

(b) $A_{12} = \begin{pmatrix} 3 & 1 \\ 4 & 5 \end{pmatrix} = (-1)^{1+2}(3\cdot5)-(1\cdot4) = -(15-4) = -11 \qquad \therefore |A_{12}| = -11$

(c) $A_{13} = \begin{pmatrix} 3 & 2 \\ 4 & 4 \end{pmatrix} = (-1)^{1+3}(3\cdot4)-(2\cdot4) = 12-8 = 4 \qquad \therefore |A_{13}| = 4$

(d) $A_{23} = \begin{pmatrix} 1 & 2 \\ 4 & 4 \end{pmatrix} = (-1)^{2+3}(1\cdot4)-(2\cdot4) = -(4-8) = 4 \qquad \therefore |A_{23}| = 4$

---

7. (a) $|A| = \begin{vmatrix} 1 & 5 & -6 \\ -1 & -4 & 4 \\ -2 & -7 & 9 \end{vmatrix} = (-1)^{1+1}\cdot1\cdot\begin{vmatrix} -4 & 4 \\ -7 & 9 \end{vmatrix} + (-1)^{1+2}\cdot5\cdot\begin{vmatrix} -1 & 4 \\ -2 & 9 \end{vmatrix} + (-1)^{1+3}\cdot(-6)\cdot\begin{vmatrix} -1 & -4 \\ -2 & -7 \end{vmatrix}$

$= 1\cdot\Big(\underbrace{((-4)\cdot9)}_{-36}-\underbrace{(4\cdot(-7))}_{-28}\Big) - 5\cdot\Big(\underbrace{((-1)\cdot9)}_{-9}-\underbrace{(4\cdot(-2))}_{-8}\Big) - 6\cdot\Big(\underbrace{((-1)\cdot(-7))}_{7}-\underbrace{((-4)\cdot(-2))}_{8}\Big)$

$= 1\cdot\underbrace{((-36)+28)}_{-8} - 5\cdot\underbrace{((-9)+8)}_{-1} - 6\cdot\underbrace{(7-8)}_{-1} = -8+5+6 = 3 \qquad \therefore |A| = 3$

(b) $|A| = \begin{vmatrix} 1 & 5 & -3 \\ 3 & -3 & 3 \\ 2 & 13 & -7 \end{vmatrix} = (-1)^{1+1}\cdot1\cdot\begin{vmatrix} -3 & 3 \\ 13 & -7 \end{vmatrix} + (-1)^{1+2}\cdot5\cdot\begin{vmatrix} 3 & 3 \\ 2 & -7 \end{vmatrix} + (-1)^{1+3}\cdot(-3)\cdot\begin{vmatrix} 3 & -3 \\ 2 & 13 \end{vmatrix}$

$= 1\cdot\Big(\underbrace{((-3)\cdot(-7))}_{21}-\underbrace{(3\cdot13)}_{39}\Big) - 5\cdot\Big(\underbrace{(3\cdot(-7))}_{-21}-\underbrace{(3\cdot2)}_{6}\Big) - 3\cdot\Big(\underbrace{(3\cdot13)}_{39}-\underbrace{((-3)\cdot(-2))}_{6}\Big)$

$= 1\cdot\underbrace{(21-39)}_{-18} - 5\cdot\underbrace{((-21)-6)}_{-27} - 3\cdot\underbrace{(39-6)}_{33} = \underbrace{1\cdot(-18)}_{-18} - \underbrace{(5\cdot(-27))}_{-135} - \underbrace{(3\cdot33)}_{99} = -18+135-99$

$= 18$

$\therefore |A| = 18$

8. (a)

$$\begin{vmatrix} 1 & 3 & 0 & 2 \\ 2 & 6 & 0 & 4 \\ -2 & -5 & 7 & 4 \\ 3 & 5 & 2 & 1 \\ 1 & -1 & 2 & -3 \end{vmatrix} \xrightarrow{R_2 \leftarrow R_2 + 2R_1} \begin{vmatrix} 1 & 3 & 0 & 2 \\ 0 & 1 & 7 & 8 \\ -3 & -9 & 0 & -6 \\ 3 & 5 & 2 & 1 \\ 1 & -1 & 2 & -3 \end{vmatrix}$$

$$\xrightarrow{R_3 \leftarrow R_3 - 3R_1} \begin{vmatrix} 1 & 3 & 0 & 2 \\ 0 & 1 & 7 & 8 \\ 0 & -4 & 2 & -5 \\ -1 & -3 & 0 & -2 \\ 1 & -1 & 2 & -3 \end{vmatrix}$$

$$\xrightarrow{R_4 \leftarrow R_4 - R_1} \begin{vmatrix} 1 & 3 & 0 & 2 \\ 0 & 1 & 7 & 8 \\ 0 & -4 & 2 & -5 \\ 0 & -4 & 2 & -5 \end{vmatrix}$$

$$\xrightarrow{R_4 \leftarrow R_4 - R_3} \begin{vmatrix} 1 & 3 & 0 & 2 \\ 0 & 1 & 7 & 8 \\ 0 & 4 & 28 & 32 \\ 0 & -4 & 2 & -5 \\ 0 & 0 & 0 & 0 \end{vmatrix}$$

$$\xrightarrow{R_3 \leftarrow R_3 - 4R_2} \begin{vmatrix} 1 & 3 & 0 & 2 \\ 0 & 1 & 7 & 8 \\ 0 & 0 & 30 & 27 \\ 0 & 0 & 0 & 0 \end{vmatrix}$$

$|A| = 1 \times 1 \times 30 \times 0 = 0$ $\quad \boxed{\therefore |A| = 0}$

8.(b)

$$|A| = \underbrace{(-1)^{2+1}\cdot 0\cdot\begin{vmatrix} 3 & 3 & -4 \\ 5 & 4 & -3 \\ -7 & -5 & 2 \end{vmatrix}}_{0} + \underbrace{(-1)^{2+2}\cdot 1\cdot\begin{vmatrix} 1 & 3 & -4 \\ 2 & 4 & -3 \\ -3 & -5 & 2 \end{vmatrix}}_{0} + \underbrace{(-1)^{2+3}\cdot 2\cdot\begin{vmatrix} 1 & 3 & -4 \\ 2 & 5 & -3 \\ -3 & -7 & 2 \end{vmatrix}}_{0} + \underbrace{(-1)^{2+4}\cdot(-5)\cdot\begin{vmatrix} 1 & 3 & 3 \\ 2 & 5 & 4 \\ -3 & -7 & -5 \end{vmatrix}}_{0}$$

$$= 0+0+0+0 = 0 \qquad \boxed{\therefore |A| = 0}$$

$$\begin{vmatrix} 1 & 3 & -4 \\ 2 & 4 & -3 \\ -3 & -5 & 2 \end{vmatrix} = (-1)^{1+1}\cdot 1\cdot\begin{vmatrix} 4 & -3 \\ -5 & 2 \end{vmatrix} + (-1)^{1+2}\cdot 3\cdot\begin{vmatrix} 2 & -3 \\ -3 & 2 \end{vmatrix} + (-1)^{1+3}\cdot(-4)\cdot\begin{vmatrix} 2 & 4 \\ -3 & -5 \end{vmatrix}$$

$$= 1\cdot 1\cdot\underbrace{(8-15)}_{-7} + (-1)\cdot 3\cdot\underbrace{(4-9)}_{-5} + 1\cdot(-4)\cdot\underbrace{(-10-(-12))}_{2} = -7+15-8 = 0$$

$$\begin{vmatrix} 1 & 3 & -4 \\ 2 & 5 & -3 \\ -3 & -7 & 2 \end{vmatrix} = (-1)^{1+1}\cdot 1\cdot\begin{vmatrix} 5 & -3 \\ -7 & 2 \end{vmatrix} + (-1)^{1+2}\cdot 3\cdot\begin{vmatrix} 2 & -3 \\ -3 & 2 \end{vmatrix} + (-1)^{1+3}\cdot(-4)\cdot\begin{vmatrix} 2 & 5 \\ -3 & -7 \end{vmatrix}$$

$$= 1\cdot 1\cdot\overbrace{(10-21)}^{-11} + (-1)\cdot 3\cdot\overbrace{(4-9)}^{-5} + 1\cdot(-4)\cdot\overbrace{(-14-(-15))}^{1} = -11+15-4 = 0$$

$$\begin{vmatrix} 1 & 3 & 3 \\ 2 & 5 & 4 \\ -3 & -7 & -5 \end{vmatrix} = (-1)^{1+1}\cdot 1\cdot\begin{vmatrix} 5 & 4 \\ -7 & -5 \end{vmatrix} + (-1)^{1+2}\cdot 3\cdot\begin{vmatrix} 2 & 4 \\ -3 & -5 \end{vmatrix} + (-1)^{1+3}\cdot 3\cdot\begin{vmatrix} 2 & 5 \\ -3 & -7 \end{vmatrix}$$

$$= 1\cdot 1\cdot\overbrace{(-25-(-28))}^{3} + (-1)\cdot 3\cdot\overbrace{(-10-(-12))}^{2} + 1\cdot 3\cdot\overbrace{(-14-(-15))}^{1} = 3-6+3 = 0$$

9.

$$\begin{vmatrix} 1 & 3 & -1 & 0 & -2 \\ 0 & 2 & -4 & -1 & -6 \\ 2 & 6 & -2 & 0 & -4 \\ -2 & -6 & 2 & 2 & 9 \\ 2 & 7 & -3 & 8 & -7 \\ 3 & 5 & 5 & 2 & 7 \end{vmatrix} \xrightarrow{R_3 \leftarrow R_3 + 2R_1} \begin{vmatrix} 1 & 3 & -1 & 0 & -2 \\ 0 & 2 & -4 & -1 & -6 \\ 0 & 0 & 0 & 2 & 5 \\ -2 & -6 & 2 & 0 & 4 \\ 2 & 7 & -3 & 8 & -7 \\ 3 & 5 & 5 & 2 & 7 \end{vmatrix}$$

$$\xrightarrow{R_4 \leftarrow R_4 - 2R_1} \begin{vmatrix} 1 & 3 & -1 & 0 & -2 \\ 0 & 2 & -4 & -1 & -6 \\ 0 & 0 & 0 & 2 & 5 \\ 0 & 1 & -1 & 8 & -3 \\ -3 & -9 & 3 & 0 & 6 \\ 3 & 5 & 5 & 2 & 7 \end{vmatrix} \xrightarrow{R_5 \leftarrow R_5 - 3R_1} \begin{vmatrix} 1 & 3 & -1 & 0 & -2 \\ 0 & 2 & -4 & -1 & -6 \\ 0 & 0 & 0 & 2 & 5 \\ 0 & 1 & -1 & 8 & -3 \\ 0 & 4 & -8 & -2 & -12 \\ 0 & -4 & 8 & 2 & 13 \end{vmatrix}$$

$$\xrightarrow{R_5 \leftarrow R_5 + 2R_1} \begin{vmatrix} 1 & 3 & -1 & 0 & -2 \\ 0 & 2 & -4 & -1 & -6 \\ 0 & -2 & 2 & -16 & 6 \\ 0 & 0 & 0 & 2 & 5 \\ 0 & 1 & -1 & 8 & -3 \\ 0 & 0 & 0 & 0 & 1 \end{vmatrix} \xrightarrow{R_2 \leftarrow R_2 - 2R_4} \begin{vmatrix} 1 & 3 & -1 & 0 & -2 \\ 0 & 0 & -2 & -17 & 0 \\ 0 & 0 & 0 & 2 & 5 \\ 0 & 1 & -1 & 8 & -3 \\ 0 & 0 & 0 & 0 & 1 \end{vmatrix}$$

$$\xrightarrow[R_3 \leftrightarrow R_4]{R_2 \leftrightarrow R_4} \begin{vmatrix} 1 & 3 & -1 & 0 & -2 \\ 0 & 1 & -1 & 8 & -3 \\ 0 & 0 & -2 & -17 & 0 \\ 0 & 0 & 0 & 2 & 5 \\ 0 & 0 & 0 & 0 & 1 \end{vmatrix} \qquad |A| = 1\cdot 1\cdot(-2)\cdot 2\cdot 1 = -4$$

$$\boxed{\therefore |A| = -4}$$

15. (a) $\det(A^3) = 3^3 = 27$ (b) $\det(A^{-1}) = \frac{1}{3}$ (c) $\det(2A) = 6$

(d) $\det(AA^{-1}) = 1$ (e) $\det(AB^{-1}) = 3 \times -\frac{1}{2} = -\frac{3}{2}$

---

16. $B = \begin{vmatrix} 1 & 0 & 1 \\ 1 & 1 & 2 \\ 1 & 2 & 1 \end{vmatrix}$ $\det(B) = (-1)^{1+1} \cdot 1 \cdot \begin{vmatrix} 1 & 2 \\ 2 & 1 \end{vmatrix} + (-1)^{1+2} \cdot 0 \cdot \begin{vmatrix} 1 & 2 \\ 1 & 1 \end{vmatrix} + (-1)^{1+3} \cdot 1 \cdot \begin{vmatrix} 1 & 1 \\ 1 & 2 \end{vmatrix}$

$= (1-4) + 0 + (2-1) = -2$

$\det(B^3) = (-2)^3 = -8$ $\boxed{\therefore \det(B^3) = -8}$

---

17. $\det(A^5) = 2^5 = 32$ $\boxed{\therefore \det(A^5) = 32}$

numpy 이용하여 행렬식 계산하기

5장 연습문제 3번

```python
import numpy as np

def matrix_determinant(matrix):
    return np.linalg.det(matrix)

# 예시 행렬
A = np.array([[5, 2, 3], [3, -1, 1],[6, 4, 2]])

# 행렬식 계산
det_A = matrix_determinant(A)
print(det_A)

```

```
23.999999999999993
```

```python
import numpy as np

def matrix_determinant(matrix):
    return np.linalg.det(matrix)

# 예시 행렬
A = np.array([[3, 2, 3], [6, 1, 2],[1, 2, 5]])

# 행렬식 계산
det_A = matrix_determinant(A)
print(det_A)

```

```
-20.000000000000014
```

5장 연습문제 7번

```
import numpy as np

def matrix_determinant(matrix):
    return np.linalg.det(matrix)

# 예시 행렬
A = np.array([[1, 5, -6], [-1, -4, 4],[-2, -7, 9]])

# 행렬식 계산
det_A = matrix_determinant(A)
print(det_A)

```

```
2.9999999999999996
```

```
import numpy as np

def matrix_determinant(matrix):
    return np.linalg.det(matrix)

# 예시 행렬
A = np.array([[1, 5, -3], [3, -3, 3],[2, 13, -7]])

# 행렬식 계산
det_A = matrix_determinant(A)
print(det_A)

```

```
-17.999999999999996
```

5장 연습문제 8번

```python
import numpy as np

def matrix_determinant(matrix):
    return np.linalg.det(matrix)

# 예시 행렬
A = np.array([[1, 3, 0, 2], [-2, -5, 7, 4], [3, 5, 2, 1], [1, -1, 2, -3]])

# 행렬식 계산
det_A = matrix_determinant(A)
print(det_A)
```

```
0.0
```

```python
import numpy as np

def matrix_determinant(matrix):
    return np.linalg.det(matrix)

# 예시 행렬
A = np.array([[1, 3, 3, -4], [0, 1, 2, -5], [2, 5, 4, -3], [-3, -7, -5, 2]])

# 행렬식 계산
det_A = matrix_determinant(A)
print(det_A)
```

```
0.0
```

5장 연습문제 9번

```python
import numpy as np

def matrix_determinant(matrix):
    return np.linalg.det(matrix)

# 예시 행렬
A = np.array([[1, 3, -1, 0, -2], [0, 2, -4, -1, -6], [-2, -6, 2, 2, 9], [2, 7, -3, 8, -7], [3, 5, 5, 2, 7]])

# 행렬식 계산
det_A = matrix_determinant(A)
print(det_A)
```

```
-3.9999999999998206
```