

MA 106 D1-T3 Recap-2

Siddhant Midha

06-04-2022

The Determinant Function

We shall consider functions of the form

$$f : \mathbb{R}^n \times \mathbb{R}^n \cdots \times \mathbb{R}^n \rightarrow \mathbb{R}$$

The Determinant Function

We shall consider functions of the form

$$f : \mathbb{R}^n \times \mathbb{R}^n \cdots \times \mathbb{R}^n \rightarrow \mathbb{R}$$

Some notions

- Multilinearity

$$f(c_1 \dots ac_i + bc'_i \dots c_n) = af(c_1 \dots c_i \dots c_n) + bf(c_1 \dots c'_i \dots c_n)$$

The Determinant Function

We shall consider functions of the form

$$f : \mathbb{R}^n \times \mathbb{R}^n \cdots \times \mathbb{R}^n \rightarrow \mathbb{R}$$

Some notions

- Multilinearity

$$f(c_1 \dots ac_i + bc'_i \dots c_n) = af(c_1 \dots c_i \dots c_n) + bf(c_1 \dots c'_i \dots c_n)$$

- Normalization

$$f(e_1, e_2 \dots e_n) = 1$$

The Determinant Function

We shall consider functions of the form

$$f : \mathbb{R}^n \times \mathbb{R}^n \cdots \times \mathbb{R}^n \rightarrow \mathbb{R}$$

Some notions

- Multilinearity

$$f(c_1 \dots ac_i + bc'_i \dots c_n) = af(c_1 \dots c_i \dots c_n) + bf(c_1 \dots c'_i \dots c_n)$$

- Normalization

$$f(e_1, e_2 \dots e_n) = 1$$

- (Skew) Symmetry

$$f(c_1, \dots c_i \dots c_j \dots c_n) = (-)f(c_1, \dots c_j \dots c_i \dots c_n)$$

The Determinant Function

Definition

A normalized, skew symmetric and multilinear function on the set of $n \times n$ matrices is called *a* determinant function.

The Determinant Function

Definition

A normalized, skew symmetric and multilinear function on the set of $n \times n$ matrices is called a determinant function.

Theorem

The determinant function exists and is unique.

The Determinant Function

Definition

A normalized, skew symmetric and multilinear function on the set of $n \times n$ matrices is called a determinant function.

Theorem

The determinant function exists and is unique.

Second Fundamental Lemma

Lemma

Let $f : \mathbb{R}^n \times \mathbb{R}^n \cdots \times \mathbb{R}^n \rightarrow \mathbb{R}$ be a multilinear function.

Second Fundamental Lemma

Lemma

Let $f : \mathbb{R}^n \times \mathbb{R}^n \cdots \times \mathbb{R}^n \rightarrow \mathbb{R}$ be a multilinear function. The following are equivalent.

Second Fundamental Lemma

Lemma

Let $f : \mathbb{R}^n \times \mathbb{R}^n \cdots \times \mathbb{R}^n \rightarrow \mathbb{R}$ be a multilinear function. The following are equivalent.

- f is skew symmetric.

Second Fundamental Lemma

Lemma

Let $f : \mathbb{R}^n \times \mathbb{R}^n \cdots \times \mathbb{R}^n \rightarrow \mathbb{R}$ be a multilinear function. The following are equivalent.

- f is skew symmetric.
- $f(c_1, c_2 \dots c_i \dots c_j \dots c_n) = 0$ whenever $c_i = c_j$.

Second Fundamental Lemma

Lemma

Let $f : \mathbb{R}^n \times \mathbb{R}^n \cdots \times \mathbb{R}^n \rightarrow \mathbb{R}$ be a multilinear function. The following are equivalent.

- f is skew symmetric.
- $f(c_1, c_2 \dots c_i \dots c_j \dots c_n) = 0$ whenever $c_i = c_j$.
- $f(c_1, c_2 \dots c_i, c_{i+1} \dots c_n) = 0$ whenever $c_i = c_{i+1}$.

Second Fundamental Lemma

Lemma

Let $f : \mathbb{R}^n \times \mathbb{R}^n \cdots \times \mathbb{R}^n \rightarrow \mathbb{R}$ be a multilinear function. The following are equivalent.

- f is skew symmetric.
- $f(c_1, c_2 \dots c_i \dots c_j \dots c_n) = 0$ whenever $c_i = c_j$.
- $f(c_1, c_2 \dots c_i, c_{i+1} \dots c_n) = 0$ whenever $c_i = c_{i+1}$.

Minors and Cofactors

Consider a matrix $A = [a_{ij}] \in \mathbb{R}^{n \times n}$.

Minors and Cofactors

Consider a matrix $A = [a_{ij}] \in \mathbb{R}^{n \times n}$.

- For each a_{ij} , deleting the corresponding row and column results in a $(n - 1) \times (n - 1)$ matrix, whose determinant we call the minor M_{ij} .

Minors and Cofactors

Consider a matrix $A = [a_{ij}] \in \mathbb{R}^{n \times n}$.

- For each a_{ij} , deleting the corresponding row and column results in a $(n-1) \times (n-1)$ matrix, whose determinant we call the minor M_{ij} .
- The cofactors are defined as, $A_{ij} := (-1)^{i+j} M_{ij}$.

Minors and Cofactors

Consider a matrix $A = [a_{ij}] \in \mathbb{R}^{n \times n}$.

- For each a_{ij} , deleting the corresponding row and column results in a $(n-1) \times (n-1)$ matrix, whose determinant we call the minor M_{ij} .
- The cofactors are defined as, $A_{ij} := (-1)^{i+j} M_{ij}$.

Theorem

For any $n \times n$ matrix A ,

Minors and Cofactors

Consider a matrix $A = [a_{ij}] \in \mathbb{R}^{n \times n}$.

- For each a_{ij} , deleting the corresponding row and column results in a $(n-1) \times (n-1)$ matrix, whose determinant we call the minor M_{ij} .
- The cofactors are defined as, $A_{ij} := (-1)^{i+j} M_{ij}$.

Theorem

For any $n \times n$ matrix A ,

$$\det(A) = \sum_{j=1}^n a_{ij} A_{ij}$$

for all $i = 1, 2, \dots, n$.

Gram Determinant

Theorem

Given k vectors $v_1, v_2 \dots v_k \in \mathbb{R}^n$, define

Gram Determinant

Theorem

Given k vectors $v_1, v_2 \dots v_k \in \mathbb{R}^n$, define

$$G := [g_{ij}]$$

where $g_{ij} := v_i^T v_j$.

Gram Determinant

Theorem

Given k vectors $v_1, v_2 \dots v_k \in \mathbb{R}^n$, define

$$G := [g_{ij}]$$

where $g_{ij} := v_i^T v_j$. The vectors $v_1, v_2 \dots v_k \in \mathbb{R}^n$ are linearly independent iff

Gram Determinant

Theorem

Given k vectors $v_1, v_2 \dots v_k \in \mathbb{R}^n$, define

$$G := [g_{ij}]$$

where $g_{ij} := v_i^T v_j$. The vectors $v_1, v_2 \dots v_k \in \mathbb{R}^n$ are linearly independent iff

$$\det(G) \neq 0$$

The Adjugate Matrix

Given a $n \times n$ matrix A

The Adjugate Matrix

Given a $n \times n$ matrix A , when we

- 1 Replace a_{ij} by A_{ij} .

The Adjugate Matrix

Given a $n \times n$ matrix A , when we

- 1 Replace a_{ij} by A_{ij} .
- 2 Take the transpose.

The Adjugate Matrix

Given a $n \times n$ matrix A , when we

- 1 Replace a_{ij} by A_{ij} .
- 2 Take the transpose.

we get what's called the *adjugate* of A .

The Adjugate Matrix

Given a $n \times n$ matrix A , when we

- 1 Replace a_{ij} by A_{ij} .
- 2 Take the transpose.

we get what's called the *adjugate* of A . Thus,

$$\text{Adj}(A) := [A_{ij}]^T$$

The Adjugate Matrix

Given a $n \times n$ matrix A , when we

- 1 Replace a_{ij} by A_{ij} .
- 2 Take the transpose.

we get what's called the *adjugate* of A . Thus,

$$\text{Adj}(A) := [A_{ij}]^T$$

We saw in class, if A is non-singular then

$$A^{-1} = \frac{\text{Adj}(A)}{\det(A)}$$