

Further linear algebra. Chapter V. Bilinear and quadratic forms.

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1 Matrix Representation.

Definition 1.1 Let V be a vector space over k . A bilinear form on V is a function $f : V \times V \rightarrow k$ such that

- $f(u + \lambda v, w) = f(u, w) + \lambda f(v, w)$;
- $f(u, v + \lambda w) = f(u, v) + \lambda f(u, w)$.

I.e. $f(v, w)$ is linear in both v and w .

An obvious example is the following : take $V = \mathbb{R}$ and $f : \mathbb{R} \times \mathbb{R} \rightarrow \mathbb{R}$ defined by $f(x, y) = xy$.

Notice here the difference between linear and bilinear : $f(x, y) = x + y$ is linear, $f(x, y) = xy$ is bilinear.

More generally $f(x, y) = \lambda xy$ is bilinear for any $\lambda \in \mathbb{R}$.

More generally still, given a matrix $A \in M_n(k)$, the following is a bilinear form on k^n :

$$f(v, w) = v^t A w = \sum_{i,j} v_i a_{i,j} w_j, \quad v = \begin{pmatrix} v_1 \\ \vdots \\ v_n \end{pmatrix}, \quad w = \begin{pmatrix} w_1 \\ \vdots \\ w_n \end{pmatrix}.$$

We'll see that in fact all bilinear form are of this form.

Example 1.1 If $A = \begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$ then the corresponding bilinear form is

$$f\left(\begin{pmatrix} x_1 \\ y_1 \end{pmatrix}, \begin{pmatrix} x_2 \\ y_2 \end{pmatrix}\right) = (x_1 \ y_1) \begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} \begin{pmatrix} x_2 \\ y_2 \end{pmatrix} = x_1 x_2 + 2x_1 y_2 + 3y_1 x_2 + 4y_1 y_2.$$

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