

# 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

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

# Further Linear Algebra

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