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### Fundamental Subspaces

In this section we want to take a look at some important subspaces that are associated with matrices. In fact they are so important that they are often called the fundamental subspaces of a matrix. We've actually already seen one of the fundamental subspaces, the null space, [previously](#) although we will give its definition here again for the sake of completeness.

Before we give the formal definitions of the fundamental subspaces we need to quickly review a concept that we first saw back when we were looking at matrix arithmetic.

Given an  $m \times n$  matrix

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

The **row vectors** (we called them row matrices at the time) are the vectors in  $\mathbb{R}^n$  formed out of the rows of  $A$ . The **column vectors** (again we called them column matrices at the time) are the vectors in  $\mathbb{R}^m$  that are formed out of the columns of  $A$ .

**Example 1** Write down the row vectors and column vectors for

$$A = \begin{bmatrix} -1 & 5 \\ 0 & -4 \\ 9 & 2 \\ 3 & -7 \end{bmatrix}$$

**Solution**

The row vectors are,

$$\mathbf{r}_1 = \begin{bmatrix} -1 & 5 \end{bmatrix} \quad \mathbf{r}_2 = \begin{bmatrix} 0 & -4 \end{bmatrix} \quad \mathbf{r}_3 = \begin{bmatrix} 9 & 2 \end{bmatrix} \quad \mathbf{r}_4 = \begin{bmatrix} 3 & -7 \end{bmatrix}$$

The column vectors are

$$\mathbf{c}_1 = \begin{bmatrix} -1 \\ 0 \\ 9 \\ 3 \end{bmatrix} \quad \mathbf{c}_2 = \begin{bmatrix} 5 \\ -4 \\ 2 \\ -7 \end{bmatrix}$$

# Pauls Notes Linear Algebra

**David Lerner**



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