

Linear Equations in More Than Two Variables

Linear equations in more than two variables arise naturally all the time in economic contexts. Adding variables does change linear equations in some radical ways; the graph of a linear equation like $x + 2y + 3z + w = 0$ is no longer a line, and in fact humans can't even visualize it! We can still apply a lot of the same reasoning with applications though.

Example:

Solve the systems of equations by elimination.

$$\begin{array}{r} \textcircled{1} \quad \left. \begin{array}{l} x + 3y = 7 \\ 5x + 4y = 2 \end{array} \right\} + \rightarrow \begin{array}{r} -5x - 15y = -35 \\ 5x + 4y = 2 \\ \hline -11y = -33 \\ y = 3 \end{array} \quad \textcircled{2}$$

③ solve for x :

$$\begin{array}{l} x + 3y = 7 \\ x + 3(3) = 7 \\ x + 9 = 7 \rightarrow x = -2 \end{array} \quad \therefore (x, y) = (-2, 3)$$

We're still going to be interested in solving systems of linear equations, and that's going to mean the same thing as before—finding the values of the variables which make all equations true simultaneously.

Example: Show that $x = 50, y = 125, z = 50$ is a solution to the following system of linear equations:

$$\begin{array}{l} 3x + 2y + 4z = 600 \\ 2x + y + z = 275 \\ 6x + 6y + 2z = 1150 \end{array} \quad \begin{array}{l} 3(50) + 2(125) + 4(50) = 600 \\ 2(50) + 125 + 50 = 275 \\ 6(50) + 6(125) + 2(50) = 1150 \end{array}$$

$$\begin{array}{l} 150 + 250 + 200 = 600 \\ 100 + 125 + 50 = 275 \\ 300 + 750 + 100 = 1150 \end{array} \quad \therefore (50, 125, 50) \text{ is a solution.}$$

Gauss-Jordan Elimination

We studied substitution previously. Substitution works well in two variables, but becomes grotesque the more variables we work with. Elimination is a method which remains comparatively simple as our number of variables increases.

The goal is going to be to perform a sequence of valid operations which transforms a system of linear equations into a system in diagonal form which has the same solutions:

$$\begin{array}{l} 3x + 2y + 4z = 600 \\ 2x + y + z = 275 \\ 6x + 6y + 2z = 1150 \end{array}$$

$$\begin{array}{l} 1x + 0y + 0z = 50 \\ 0x + 1y + 0z = 125 \\ 0x + 0y + 1z = 50 \end{array}$$

$$\left[\begin{array}{ccc|c} 1 & 0 & 0 & 50 \\ 0 & 1 & 0 & 125 \\ 0 & 0 & 1 & 50 \end{array} \right]$$

There are going to be three operations we can perform which will change our system but not change the solutions which we call the Elementary Row Operations.

Interchange: Swap any two rows.

$$\begin{array}{l} x + 2y = 4 \dots R_1 \\ 2x + 3y = 6 \dots R_2 \end{array}$$

$$R_1 \leftrightarrow R_2$$

$$\begin{cases} 2x + 3y = -6 \\ x - 2y = 4 \end{cases}$$

$$\begin{cases} 1x + 0y = 0 \\ 0x + 1y = -2 \end{cases}$$

Scaling: Multiply an equation by a nonzero number.

$$\begin{array}{l} x + 2y = 4 \\ 2x + 3y = 6 \end{array}$$

$$-2R_1 \rightarrow R_1$$

$$\begin{cases} -x + 4y = -8 \\ 2x + 3y = -6 \end{cases}$$

Replacement: Add a multiple of an equation to another equation.

$$\begin{array}{l} 2x + 4y = 8 \\ 2x + 3y = 6 \end{array}$$

$$R_1 + R_2 \rightarrow R_2$$

$$\begin{cases} -2x + 4y = -8 \\ 0x + 7y = -6 \end{cases} \rightarrow y = -2$$

$$\begin{array}{l} \text{solve for } x: \\ -2x + 4(-2) = -8 \\ -2x - 8 = -8 \rightarrow -2x = 0 \\ x = 0 \end{array}$$

The examples above demonstrate two things. First, the notation we use to communicate and keep track of what we're doing. Second, how elimination works to produce an answer. By using replacement, we eliminated the coefficient of x in the second equation, producing an equation that will give us a solution for y .

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