Solutions to All Exercises

1 Systems of Linear Equations and Matrices

Exercise Set 1.1

In Section 1.1 of the text, Gaussian Elimination is used to solve a linear system. This procedure utilizes three operations that when applied to a linear system result in a new system that is equivalent to the original. Equivalent means that the linear systems have the same solutions. The three operations are:

- Interchange two equations.
- Multiply any equation by a nonzero constant.
- Add a multiple of one equation to another.

When used judiciously these three operations allow us to reduce a linear system to a triangular linear system, which can be solved. A linear system is consistent if there is at least one solution and is inconsistent if there are no solutions. Every linear system has either a unique solution, infinitely many solutions or no solutions. For example, the triangular linear systems

$$\begin{cases} x_1 - x_2 + x_3 & = 2 \\ x_2 - 2x_3 & = -1 \\ x_3 & = 2 \end{cases}, \quad \begin{cases} x_1 - 2x_2 + x_3 & = 2 \\ -x_2 + 2x_3 & = -3 \\ \end{cases}, \quad \begin{cases} 2x_1 & + x_3 & = 1 \\ x_2 & - x_3 & = 2 \\ 0 & = 4 \end{cases}$$

have a unique solution, infinitely many solutions, and no solutions, respectively. In the second linear system, the variable x_3 is a free variable, and once assigned any real number the values of x_1 and x_2 are determined. In this way the linear system has infinitely many solutions. If a linear system has the same form as the second system, but also has the additional equation $0 = 0$, then the linear system will still have free variables. The third system is inconsistent since the last equation $0 = 4$ is impossible. In some cases, the conditions on the right hand side of a linear system are not specified. Consider for example, the linear system

$$\begin{cases} -x_1 - x_2 & = a \\ 2x_1 + 2x_2 + x_3 & = b \text{ which is equivalent to} \\ 2x_3 & = c \end{cases} \xrightarrow{\qquad} \begin{cases} -x_1 - x_2 & = a \\ x_3 & = b + 2a \\ 0 & = c - 2b - 4a \end{cases}.$$

This linear system is consistent only for values a, b and c such that $c - 2b - 4a = 0$.

■ Solutions to Exercises

1. Applying the given operations we obtain the equivalent triangular system

$$\begin{cases} x_1 - x_2 - 2x_3 & = 3 \\ -x_1 + 2x_2 + 3x_3 & = 1 \\ 2x_1 - 2x_2 - 2x_3 & = -2 \end{cases} \xrightarrow{E_1 + E_2 \to E_2} \begin{cases} x_1 - x_2 - 2x_3 & = 3 \\ x_2 + x_3 & = 4 \\ 2x_1 - 2x_2 - 2x_3 & = -2 \end{cases} \xrightarrow{(-2)E_1 + E_3 \to E_3}$$

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