# Linear Algebra

## Deep Learning Pre-Work

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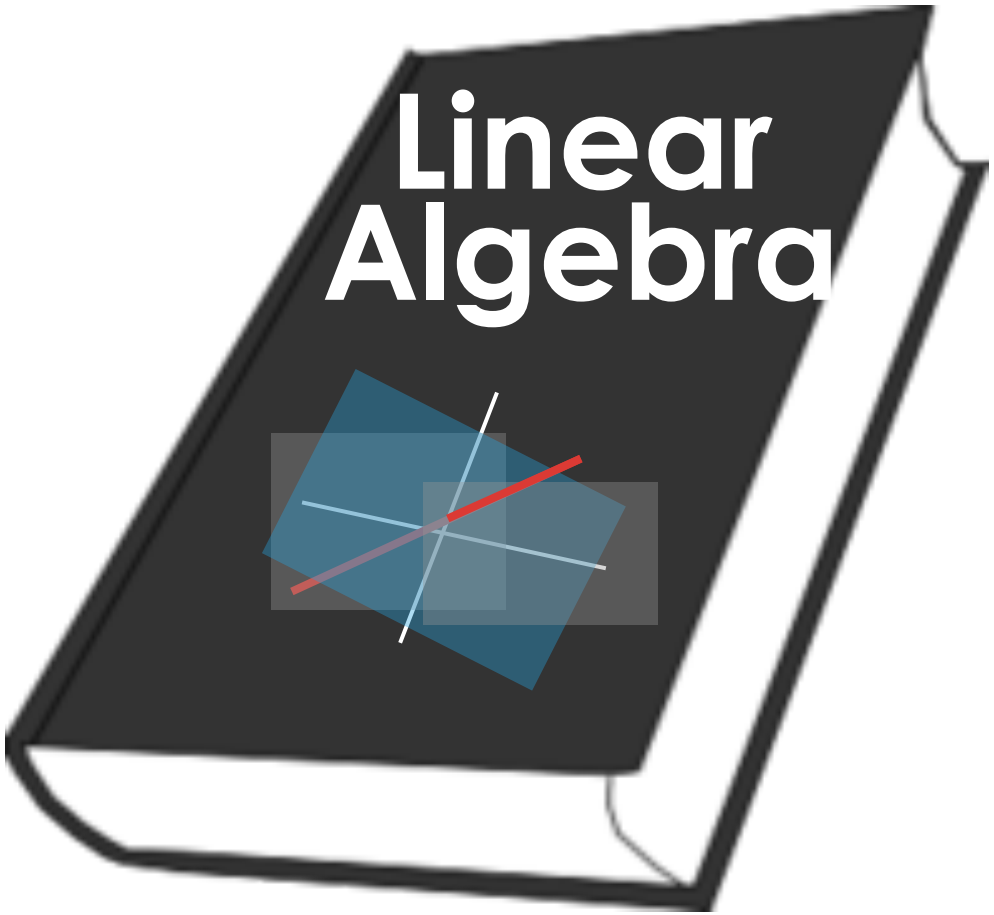
# What is linear algebra?

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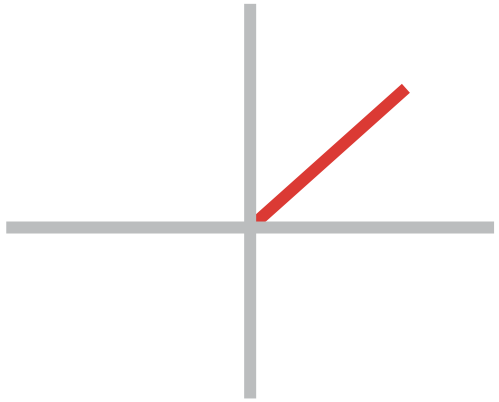
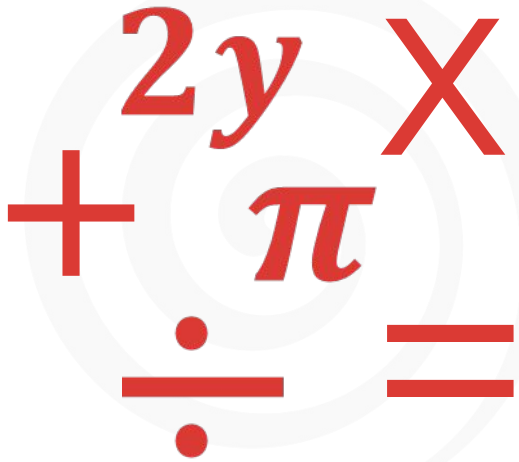
# What is linear algebra?

# Linear Algebra



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# Linear Algebra in Data Science

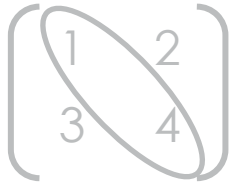
Transpose of a matrix

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{pmatrix} \rightarrow \begin{pmatrix} 1 & 3 & 5 \\ 2 & 4 & 6 \end{pmatrix}$$

Inverse of a matrix

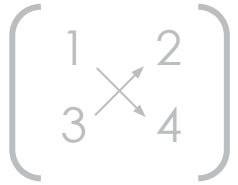
$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} X \begin{pmatrix} ? \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

Trace of a matrix




$\rightarrow 1+4$

Determinant of a matrix




$\rightarrow 1*4 - 2*3$

Eigenvector

Matrix Arithmetic

$= \pi$
$X +$

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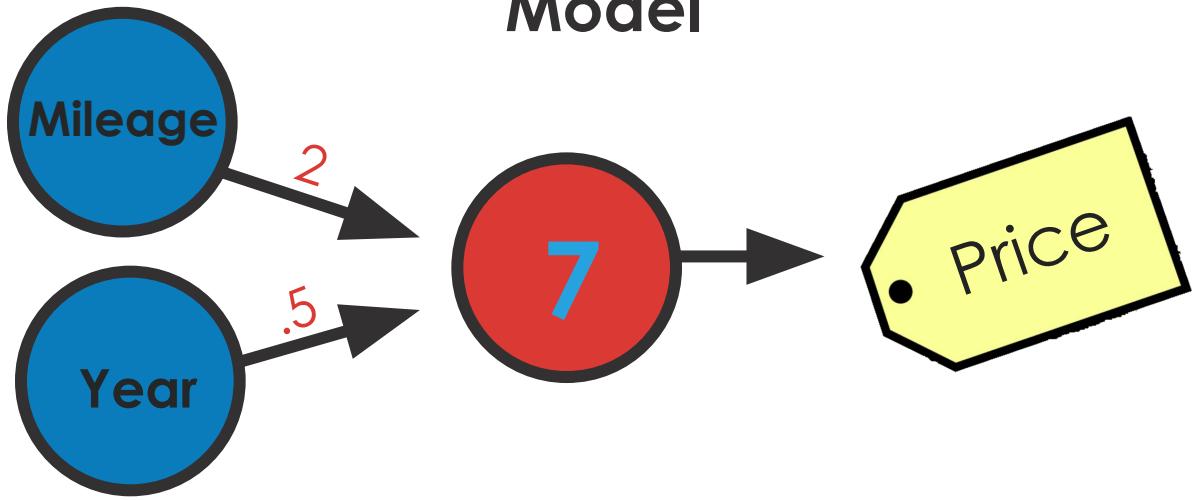
# Matrix Arithmetic in Deep Learning

**Data**

| mileage | year |
|---|---|
| 7413 | 2011 |
| 10926 | 2011 |
| 7351 | 2011 |
| 11613 | 2011 |

**Model**




Equation

$$X * Weight + Bias$$

$$\begin{pmatrix} 7{,}413 & 2011 \\ 10{,}926 & 2011 \\ 7351 & 2011 \\ 11{,}613 & 2011 \end{pmatrix} * \begin{pmatrix} 2 \\ .5 \end{pmatrix} + 7$$

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# Matrix Addition

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} + \begin{pmatrix} 5 & 6 \\ 7 & 8 \end{pmatrix} =$$

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# Matrix Addition

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} + \begin{pmatrix} 5 & 6 \\ 7 & 8 \end{pmatrix} = \begin{pmatrix} 6 & \\ & \end{pmatrix}$$

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# Matrix Addition

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} + \begin{pmatrix} 5 & 6 \\ 7 & 8 \end{pmatrix} = \begin{pmatrix} 6 & 8 \\ & \end{pmatrix}$$

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# Matrix Addition

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} + \begin{pmatrix} 5 & 6 \\ 7 & 8 \end{pmatrix} = \begin{pmatrix} 6 & 8 \\ 10 & \end{pmatrix}$$

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# Matrix Addition

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} + \begin{pmatrix} 5 & 6 \\ 7 & 8 \end{pmatrix} = \begin{pmatrix} 6 & 8 \\ 10 & 12 \end{pmatrix}$$

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# Matrix Addition

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} + \begin{pmatrix} 5 & 6 \\ 7 & 8 \end{pmatrix} = \begin{pmatrix} 6 & 8 \\ 10 & 12 \end{pmatrix}$$

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# Matrix Subtraction

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} - \begin{pmatrix} 5 & 6 \\ 7 & 8 \end{pmatrix} = \begin{pmatrix} -4 & -4 \\ -4 & -4 \end{pmatrix}$$

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# Matrix Multiplication (Hadamard Product)

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} X \begin{pmatrix} 5 & 6 \\ 7 & 8 \end{pmatrix} = \begin{pmatrix} 5 & 12 \\ 21 & 32 \end{pmatrix}$$

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# Matrix Division

$$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix} / \begin{pmatrix} 5 & 6 \\ 7 & 8 \end{pmatrix} = \begin{pmatrix} 1/5 & 2/6 \\ 3/7 & 4/8 \end{pmatrix}$$

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# Matrix Multiplication (dot product)

**Data**

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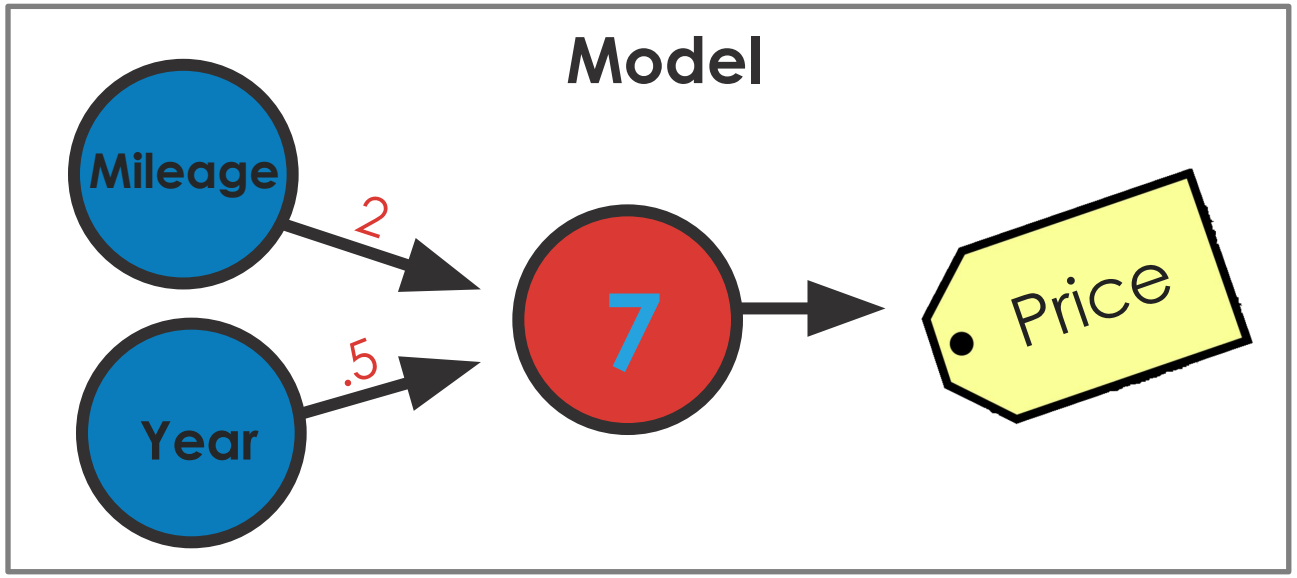


Equation

$$X * Weight + Bias$$

$$\begin{pmatrix} 7{,}413 & 2011 \\ 10{,}926 & 2011 \\ 7351 & 2011 \\ 11{,}613 & 2011 \end{pmatrix} * \begin{pmatrix} 2 \\ .5 \end{pmatrix} + 7$$

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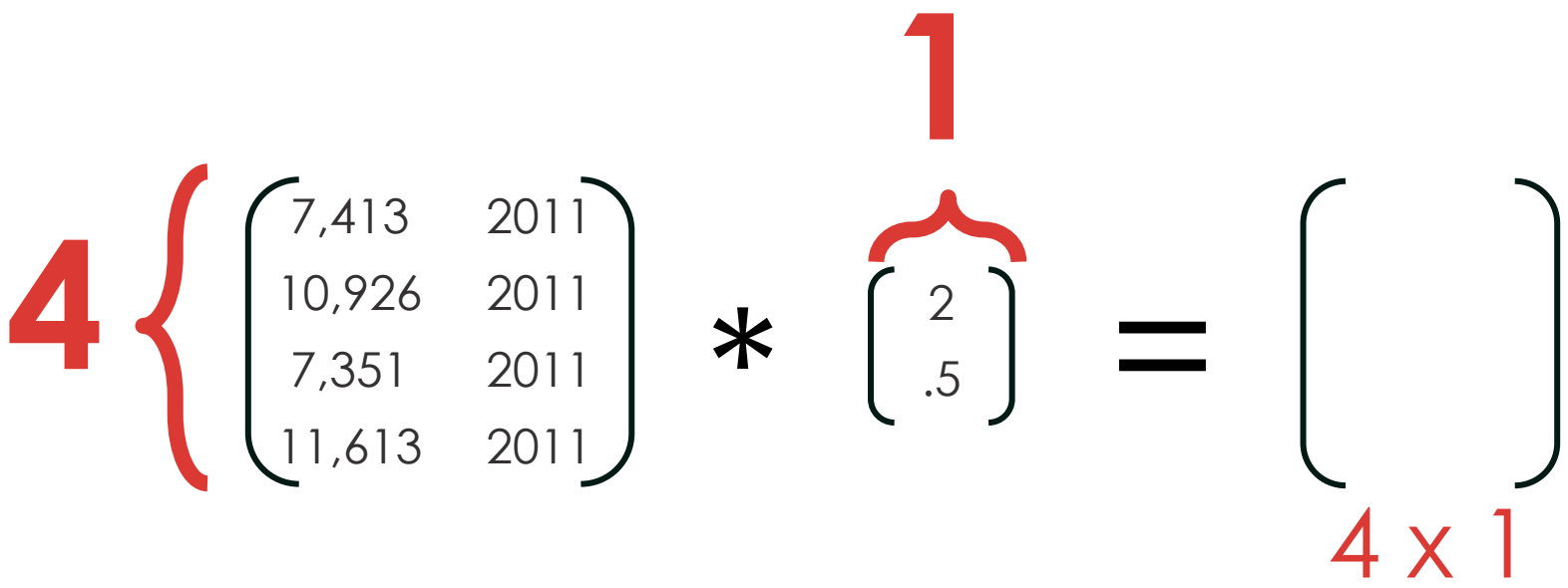
# Matrix Multiplication (dot product)

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# Matrix Multiplication (dot product)

$$\begin{pmatrix} 7{,}413 & 2011 \\ 10{,}926 & 2011 \\ 7{,}351 & 2011 \\ 11{,}613 & 2011 \end{pmatrix} * \begin{pmatrix} 2 \\ .5 \end{pmatrix} = \begin{pmatrix} (7{,}413 * 2) \\ \\ \\ \\ \end{pmatrix}$$

4 x 1

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# Matrix Multiplication (dot product)

$$\begin{pmatrix} 7{,}413 & 2011 \\ 10{,}926 & 2011 \\ 7{,}351 & 2011 \\ 11{,}613 & 2011 \end{pmatrix} * \begin{pmatrix} 2 \\ .5 \end{pmatrix} = \begin{pmatrix} (7{,}413 * 2) + (2011 * .5) \\ \\ \\ \end{pmatrix}$$

4 x 1

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# Matrix Multiplication (dot product)

$$\begin{pmatrix} 7{,}413 & 2011 \\ 10{,}926 & 2011 \\ 7{,}351 & 2011 \\ 11{,}613 & 2011 \end{pmatrix} * \begin{pmatrix} 2 \\ .5 \end{pmatrix} = \begin{pmatrix} (7{,}413 * 2) + (2011 * .5) = \mathbf{15{,}831.5} \\ \\ \\ \\ \end{pmatrix}$$

4 x 1

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# Matrix Multiplication (dot product)

$$\begin{pmatrix} 7{,}413 & 2011 \\ 10{,}926 & 2011 \\ 7{,}351 & 2011 \\ 11{,}613 & 2011 \end{pmatrix} * \begin{pmatrix} 2 \\ .5 \end{pmatrix} = \begin{pmatrix} \mathbf{15{,}831.5} \\ (10{,}926 * 2) + (2011 * .5) = \mathbf{22{,}857.5} \\ \\ \end{pmatrix}$$

4 x 1

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# Matrix Multiplication (dot product)

$$\begin{pmatrix} 7{,}413 & 2011 \\ 10{,}926 & 2011 \\ 7{,}351 & 2011 \\ 11{,}613 & 2011 \end{pmatrix} * \begin{pmatrix} 2 \\ .5 \end{pmatrix} = \begin{pmatrix} \mathbf{15{,}831.5} \\ \mathbf{22{,}857.5} \\ (7{,}351 * 2) + (2011 * .5) = \mathbf{15{,}707.5} \\ \end{pmatrix}$$

4 x 1

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# Matrix Multiplication (dot product)

$$\begin{pmatrix} 7{,}413 & 2011 \\ 10{,}926 & 2011 \\ 7{,}351 & 2011 \\ 11{,}613 & 2011 \end{pmatrix} * \begin{pmatrix} 2 \\ .5 \end{pmatrix} = \begin{pmatrix} \mathbf{15{,}831.5} \\ \mathbf{22{,}857.5} \\ \mathbf{15{,}707.5} \\ (11{,}613 * 2) + (2011 * .5) = \mathbf{24{,}231.5} \end{pmatrix}$$

4 x 1

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# Matrix Multiplication (dot product)

$$\begin{pmatrix} 7{,}413 & 2011 \\ 10{,}926 & 2011 \\ 7{,}351 & 2011 \\ 11{,}613 & 2011 \end{pmatrix} * \begin{pmatrix} 2 \\ .5 \end{pmatrix} = \begin{pmatrix} 15{,}831.5 \\ 22{,}857.5 \\ 15{,}707.5 \\ 24{,}231.5 \end{pmatrix}$$

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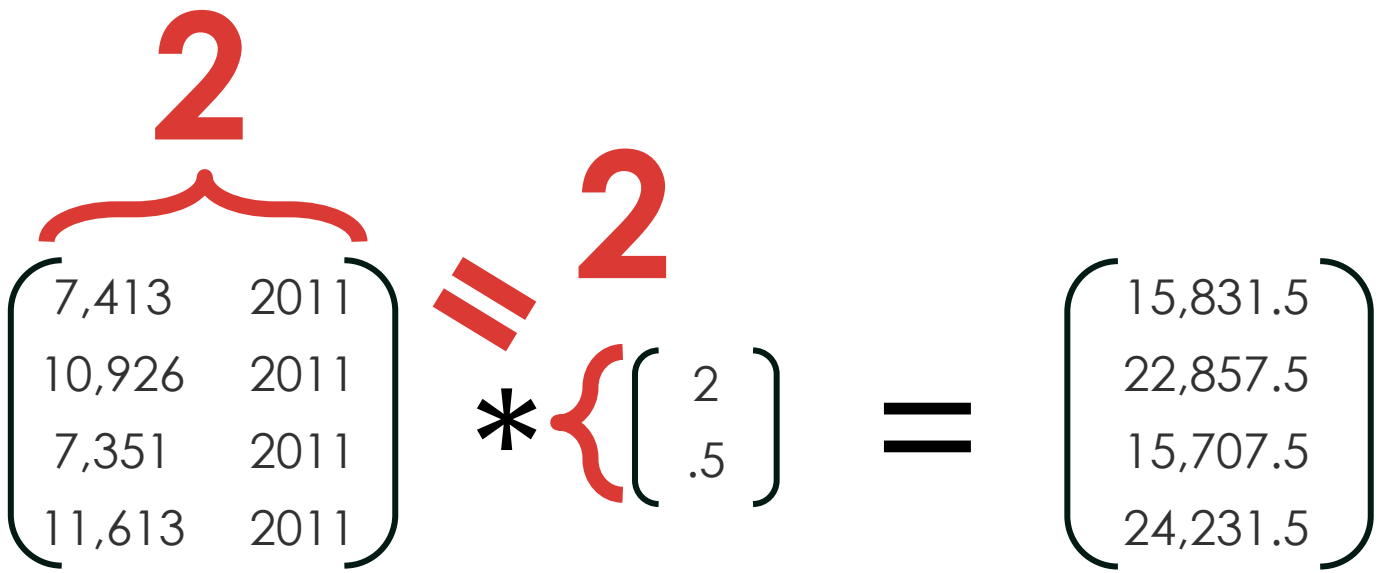
# Matrix Multiplication (dot product)

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# Matrix Scalar Addition

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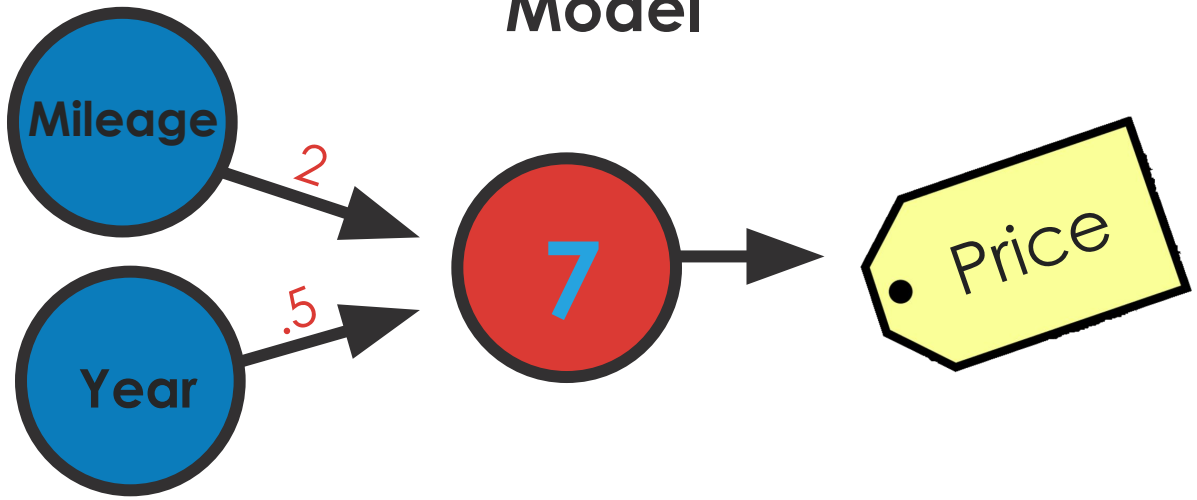
| 11613 | 2011 |

**Model**




Equation

$$X * Weight + Bias$$

$$\begin{pmatrix} 7{,}413 & 2011 \\ 10{,}926 & 2011 \\ 7351 & 2011 \\ 11{,}613 & 2011 \end{pmatrix} * \begin{pmatrix} 2 \\ .5 \end{pmatrix} + 7$$

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# Matrix Scalar Addition

$$\begin{pmatrix} 15{,}831 \\ 22{,}875.6 \\ 15{,}707.5 \\ 24{,}231.5 \end{pmatrix} + 7 = \begin{pmatrix} 15{,}831 + 7 = \mathbf{15{,}838.5} \\ 22{,}857.5 + 7 = \mathbf{22{,}864.5} \\ 15{,}707.5 + 7 = \mathbf{15{,}714.5} \\ 24{,}231.5 + 7 = \mathbf{24{,}238.5} \end{pmatrix}$$

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# Matrix Scalar Addition

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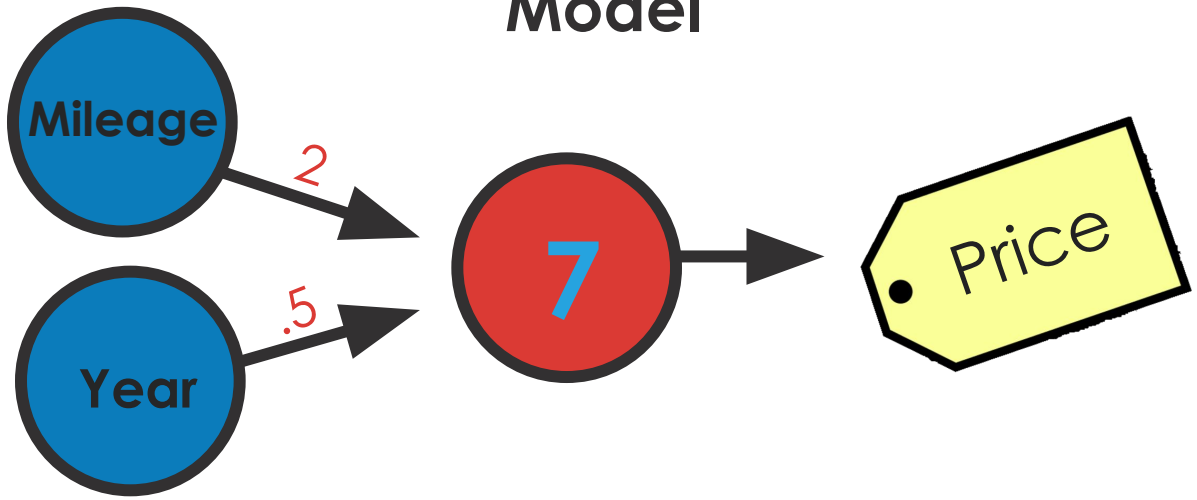
| 11613 | 2011 |

**Model**




Equation

$$X * Weight + Bias$$

$$\begin{pmatrix} 7{,}413 & 2011 \\ 10{,}926 & 2011 \\ 7351 & 2011 \\ 11{,}613 & 2011 \end{pmatrix} * \begin{pmatrix} 2 \\ .5 \end{pmatrix} + 7 = \begin{pmatrix} 15{,}839.5 \\ 22{,}865.5 \\ 15{,}714.5 \\ 24{,}239.5 \end{pmatrix}$$

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