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4.4.2 Linear Transformations to Matrix-Matrix Multiplication

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Week 4 due Oct 24, 2023 19:42 IST Completed

4.4.2 Linear Transformations to Matrix-Matrix Multiplication

Summary

Let $L_A : \mathbb{R}^k \rightarrow \mathbb{R}^m$ and $L_B : \mathbb{R}^n \rightarrow \mathbb{R}^k$ are linear transformations and define $L_C(x) = L_A(L_B(x))$. Then

- ▶ $L_C : \mathbb{R}^n \rightarrow \mathbb{R}^m$ is a linear transformation.
- ▶ There are $A \in \mathbb{R}^{m \times k}$ and $B \in \mathbb{R}^{k \times n}$ that represent L_A and L_B , respectively.
- ▶ There is a matrix, $C \in \mathbb{R}^{m \times n}$ that represents $L_C(x) = L_A(L_B(x)) = A(Bx)$.
- ▶ The operation that computes C from A and B is called matrix-matrix multiplication.
- ▶ Notation: $\underline{C} = \underline{A}\underline{B}$ and $\underline{C}x = \overline{(\underline{A}\underline{B})}x = \overline{(\underline{A}(\underline{B}x))}$.

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Homework 4.4.2.1

1/1 point (graded)
Let $L_A : \mathbb{R}^k \rightarrow \mathbb{R}^m$ and $L_B : \mathbb{R}^n \rightarrow \mathbb{R}^k$ both be linear transformations and, for all $x \in \mathbb{R}^n$, define the function $L_C : \mathbb{R}^n \rightarrow \mathbb{R}^m$ by $L_C(x) = L_A(L_B(x))$.

L_C is a linear transformation.

Always ▾

✔ Answer: Always

Explanation
Let $x, y \in \mathbb{R}^n$ and $\alpha \in \mathbb{R}$.
$$\begin{aligned} L_C(\alpha x) &= L_A(L_B(\alpha x)) \\ &= L_A(\alpha L_B(x)) \\ &= \alpha L_A(L_B(x)) \\ &= \alpha L_C(x) \end{aligned}$$
$$\begin{aligned} L_C(x + y) &= L_A(L_B(x + y)) \\ &= L_A(L_B(x) + L_B(y)) \\ &= L_A(L_B(x)) + L_A(L_B(y)) \\ &= L_C(x) + L_C(y) \end{aligned}$$

This proves that L_C is a linear transformation by showing that L_C has all the properties of a linear transformation. This proof simply states that the composition of two linear transformations is itself a linear transformation.

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Homework 4.4.2.2

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Let $A \in \mathbb{R}^{m \times n}$. $A^T A$ is well-defined. (By well-defined we mean that $A^T A$ makes sense. In this particular case this means that dimensions of A^T and A are such that $A^T A$ can be computed.)

Always ▾

✔ Answer: Always

Explanation
Answer: Always A^T is $n \times m$ and A is $m \times n$, and hence the column size of A^T matches the row size of A .

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Homework 4.4.2.3

1/1 point (graded)
Let $A \in \mathbb{R}^{m \times n}$. AA^T is well-defined.

Always ▾

✔ Answer: Always

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Explanation

Answer: Always
Apply the result in the last exercise, with A replaced by A^T .

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