MAT250S25 Proof 2

Kishan S Patel

February 13, 2025

Definition 1 ($\mathcal{L}_1$, from the **Big Thereom™**). A set of vectors is linearly dependent if and only if it is injective

Definition 2 ($\mathcal{L}_2$, from the **Big Thereom™**). A set of vectors $\{\vec{x}_1, \vec{x}_2, \ldots, \vec{x}_k\}$ is linearly dependent if and only if:

$$\begin{bmatrix}\vec{x}_1 & \vec{x}_2 & \cdots & \vec{x}_k\end{bmatrix}\vec{b} = \vec{0} \iff \vec{b} = \vec{0}$$

Given:

- let $\mathbb{R}^n$,$\mathbb{R}^m$ be Euclidean spaces.
- let $T : \mathbb{R}^m \to \mathbb{R}^n$ be a linear transformation with corresponding $n \times m$ matrix A.
- let $\vec{x}_1, \vec{x}_2, \ldots, \vec{x}_k \in \mathbb{R}^m$ be vectors such that the set of vectors
- $\{T(\vec{x}_1), T(\vec{x}_2), \ldots, T(\vec{x}_k)\}$ is linearly independent.

Prove that the set of vectors $\{\vec{x}_1, \vec{x}_2, \ldots, \vec{x}_k\}$ is linearly independent.

Proof.

$$\begin{aligned}\forall X \in M_{n\times m}\, f_X &: \vec{b} \mapsto X\vec{b}\\ &: \mathbb{R}^m \to \mathbb{R}^n\end{aligned}$$

$$\begin{aligned}\text{let } C &= \begin{bmatrix}T(\vec{x}_1) & T(\vec{x}_2) & \cdots & T(\vec{x}_k)\end{bmatrix}\\ \text{let } B &= \begin{bmatrix}\vec{x}_1 & \vec{x}_2 & \cdots & \vec{x}_k\end{bmatrix}\\ C &= A \circ B\end{aligned}$$

$$\begin{aligned}f_C &= T \circ f_B\\ \mathcal{L}_1 \implies \forall \vec{a}, \vec{b} :\ & f_C(\vec{a}) = f_C(\vec{b}) \iff \vec{a} = \vec{b}\end{aligned}$$

$$\begin{aligned}\text{let } \vec{b}, \vec{c} &\in \mathbb{R}^k\\ f_B(\vec{b}) &= f_B(\vec{c})\\ (T \circ f_B)(\vec{b}) &= (T \circ f_B)(\vec{c})\\ f_C(\vec{b}) &= f_C(\vec{c})\\ \vec{b} &= \vec{c}\end{aligned}$$

$$\begin{aligned}&\therefore f_B \text{ is injective}\\ &\implies \forall \vec{b}, \vec{c} \in \mathbb{R}^k :\ B\vec{b} = B\vec{c} \iff \vec{b} = \vec{c}\\ &\implies \forall \vec{b} \in \mathbb{R}^k :\ B\vec{b} = \vec{0} \iff \vec{b} = \vec{0}\\ \cdots \wedge \mathcal{L}_2 &\implies \{\vec{x}_1, \vec{x}_2, \cdots, \vec{x}_k\} \text{ is linearly independent.}\end{aligned}$$

QED