Source:

1 | Problem

Suppose U and V are finite-dimensional vector spaces and $S \in \mathcal{L}(V, w)$ and $T \in \mathcal{L}(U, V)$. Prove that

$$\text{dim range } ST \leq \min\{\text{dim range } S, \text{dim range } T\}.$$

2 | Proof

All vectors $v \in$ null ST must have been nulled by T or S, and therefore must be in null T or range $T \cap$ null S. Notationally,

$$\text{null } ST = \text{null } T \cup (\text{range } T \cap \text{null } S)$$

Because no vector can be in both null T and range T, the dimension of the union is

$$\text{dim null } ST = \text{dim null } T + \text{dim } (\text{range } T \cap \text{null } S)$$

Because an intersection can only make the dimension of a set smaller, dim $(\text{range } T \cap \text{null } S) \leq$ dim null S and

$$\text{dim range } ST \leq \min\{\text{dim range } S, \text{dim range } T\}$$