# Matrix theory - Assignment 10

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***Abstract*—This document illustrates applications of Rank-Nullity Theorem**

Download latex-tikz from

https://github.com/shreeprasadbhat/matrix−theory/blob/master/assignment10/

## 1 Problem

Let $\mathbf{A}$ be an $m \times n$ matrix with entries in $F$ and let $T$ be the linear transformation from $F^{n\times 1}$ into $F^{m\times l}$ defined by $T(\mathbf{X}) = \mathbf{AX}$. Show that if $m < n$ it may happen that $T$ is onto without being non-singular. Similarly, show that if $m > n$ we may have $T$ non-singular but not onto.

## 2 Solution

A linear transformation is called *singular* if it has non-zero nullity, that is it's nullspace contains atleast one non-zero vector, otherwise it is called *non-singular*.

1) if $m < n$

$$\implies dim\ Col(\mathbf{A}) < n \tag{2.0.1}$$

Hence $T(\mathbf{X})$ can be onto.

From Rank-Nullity Theorem,

$$dim\ Col(\mathbf{A}) + dim\ Null(\mathbf{A}) = n \tag{2.0.2}$$

From (2.0.1) and (2.0.2)

$$dim\ Null(\mathbf{A}) \neq 0 \tag{2.0.3}$$

$\therefore T(\mathbf{X})$ is not a non-singular transformation.

Hence if $m < n$ it may happen that $T$ is onto without being non-singular.

2) if $m > n$

$$\implies dim\ col(\mathbf{A}) > n \tag{2.0.4}$$

Assume $\mathbf{A}$ is not singular.

$$\text{If } T(\mathbf{X}) = \mathbf{0} \tag{2.0.5}$$
$$\mathbf{AX} = \mathbf{0} \tag{2.0.6}$$
$$\implies \mathbf{X} = \mathbf{0} \tag{2.0.7}$$

Hence T(X) may be a non-singular.

$$\implies dim\ Null(\mathbf{A}) = 0 \tag{2.0.8}$$

But Rank-Nullity Theorem is not satisfied,

$$\because dim\ Col(\mathbf{A}) + dim\ Null(\mathbf{A}) \neq n \tag{2.0.9}$$

From (2.0.9), we can say $T(\mathbf{X})$ do not span $F_{m\times 1}$ and $T(\mathbf{X})$ is not onto.

Hence if $m > n$ it may have that $T$ is non-singular but not onto.