Christopher David Miller
FSMAT 201
Problem 1.8
Version 2

1.8

Proposition 1. *Let* $\mathbf{u} \in \mathbb{R}^n$*. Prove that the normalization of* $\boldsymbol{u}$ *has norm 1.*

Proof. Let $\mathbf{u} \in \mathbb{R}^n$. The normalization of a vector $\mathbf{u}$ is the vector $\mathbf{v}$ given by

$$\mathbf{v} = \frac{\mathbf{u}}{\|\mathbf{u}\|}.$$

The norm of a vector $\mathbf{u}$ is the scalar $\|\mathbf{u}\|$ given by

$$\|\mathbf{u}\| = \sqrt{\sum_{k=1}^{n} u_k^2} \text{ ,where } \mathbf{u} = \begin{bmatrix} u_1 & u_2 & u_3 \dots u_k \end{bmatrix}^T.$$

In order to show the normalization of a vector $\mathbf{u}$ has norm 1, we find the normalization of $\mathbf{u}$:

$$\frac{\mathbf{u}}{\|\mathbf{u}\|}.$$

Now we must calculate the norm of the normalization of $\mathbf{u}$:

$$\begin{aligned}
\|\text{Normalization of } \mathbf{u}\| &= \sqrt{\sum_{k=1}^{n} \left(\frac{u_k}{\|\mathbf{u}\|} \right)^2} \text{ ,where normalization of } \mathbf{u} = \begin{bmatrix} \frac{u_1}{\|\mathbf{u}\|} & \frac{u_2}{\|\mathbf{u}\|} & \frac{u_3}{\|\mathbf{u}\|} \cdots \frac{u_k}{\|\mathbf{u}\|} \end{bmatrix}^T. \\
&= \sqrt{\sum_{k=1}^{n} \frac{u_k^2}{\|\mathbf{u}\|^2}} \\
&= \sqrt{\frac{1}{\|\mathbf{u}\|^2} \sum_{k=1}^{n} u_k^2} \\
&= \frac{1}{\|\mathbf{u}\|} \sqrt{\sum_{k=1}^{n} u_k^2} \\
&= \frac{1}{\|\mathbf{u}\|} \|\mathbf{u}\| \\
&= 1.
\end{aligned}$$

So from the above steps we see that the normalization of a vector has norm 1. □

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Problems 1.1
Version 1

1.1

Proposition 2. *Let* $\mathbf{v} = [1, 2, 3, \ldots, n]^T$ *and* $\mathbf{w} = [1, 1, 1 \ldots, 1]^T$*, where* $\mathbf{v}, \mathbf{w} \in \mathbb{R}^n$*.*

(a) Compute $\mathbf{v} \cdot \mathbf{w}$.

Solution : The dot product between two vectors can be written in summation notation. As the following:

$$\sum_{i=1}^{n} v_i w_i$$

So for this problem we have the following:

$$\mathbf{v} \cdot \mathbf{w} = 1 \cdot 1 + 2 \cdot 1 + 3 \cdot 1 + \cdots + 1 \cdot n$$

which is the same as :

$$\sum_{i=1}^{n} i$$

(b) Compute $\|\mathbf{v}\|$.

Solution : We first remind ourselves of the definition of the norm of a vector $\mathbf{u}$ to be the following:

$$\|\mathbf{u}\| = \sqrt{\sum_{k=1}^{n} v_k^2}$$

Using this definition and substituting we get:

$$\|\mathbf{v}\| = \sqrt{1^2 + 2^2 + 3^2 + \cdots + n^2}$$

(c) Compute $\|\mathbf{w}\|$.

Solution : Similarily using the definition from part (a) we can calculate the norm of a vector $\mathbf{w}$ like the following:

$$\begin{aligned} \|\mathbf{w}\| &= \sqrt{1^2 + 1^2 + 1^2 + \cdots + 1^2} \\ &= \sqrt{1 + 1 + 1 + \cdots + 1} \\ &= \sqrt{n} \end{aligned}$$

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Problems 1.3
Version 1

1.3

Proposition 3. *Let c be a real number and let $\mathbf{v} \in \mathbb{R}^n$ with $v_k = c$ for $k = 1, 2, \ldots, n$. Find $\|\mathbf{v}\|$.*

Solution : The norm $\|\mathbf{v}\|$ of a vector $\mathbf{v}$ can be written in summation notation. Like the following:

$$\|\mathbf{v}\| = \sqrt{\sum_{k=1}^{n} v_k^2}$$

So in our case we replace v_k with c then we have:

$$\begin{aligned} \|\mathbf{v}\| &= \sqrt{c^2 + c^2 + c^2 + \cdots + c^2} \\ &= \sqrt{nc^2} \\ &= \sqrt{n} \cdot |c| \end{aligned}$$

Which is our final result.