

# From Math to Machines: A Comprehensive Guide to ML and DL

Covering Calculus, Linear Algebra and Statistics

**Francesco Danese**

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# Linear Algebra

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## 1. Vectors and Matrices

### 1.1 Vectors

In the vast field of mathematics, vectors play a fundamental role in various branches from physics and engineering to computer science and data analysis. A vector can be thought as a ordered sequence of numbers that defines a directed line segment in space, an arrow pointing from one point to another, capturing both the **magnitude** and the **direction** in which it is pointing. We can denote a vector using a bold letter such as " $\mathbf{v}$ ", and writing down its components, for example:

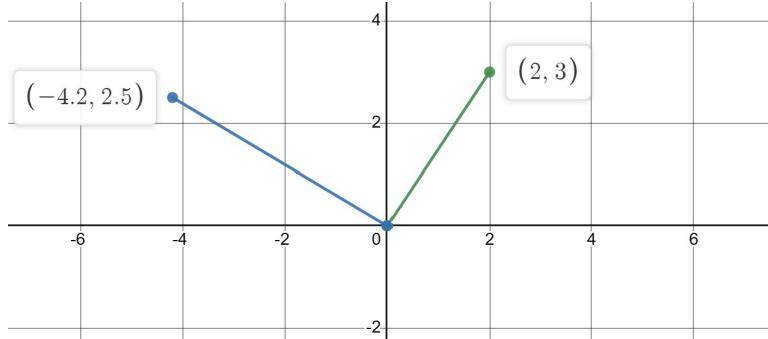
$$\mathbf{v} = \begin{bmatrix} 2 \\ 3 \end{bmatrix} \quad \mathbf{w} = \begin{bmatrix} -4.2 \\ 2.5 \end{bmatrix} \quad \mathbf{u} = \begin{bmatrix} 2.1 \\ 0 \\ -3 \end{bmatrix}$$

Each vector has a **dimensionality** (i.e.the number of its components) that tells the space in which it lives, denoted as  $R^D$ . Vectors  $\mathbf{v}$  and  $\mathbf{w}$  above live in  $R^2$  while  $\mathbf{u}$  lives in  $R^3$ . The representation is usually column-wise, but we can obtain the row-wise version of a vector by a **transposition** operation denoted as  $\mathbf{v}^T$ , for instance:

$$\mathbf{v}^T = [2 \ 3] \quad \mathbf{w}^T = [-4.2 \ 2.5] \quad \mathbf{u}^T = [2.1 \ 0 \ -3]$$

We can visualize a 2-dimensional vector by plotting it into a cartesian plane, where the two components are the shifts in the  $x$  and  $y$  directions respectively:

Figure 1.1: Vectors  $v$  and  $w$  graphically.



### 1.1.1 Subsection Title

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## Unnumbered Section

### Unnumbered Subsection

#### Unnumbered Subsubsection



## 2. In-text Element Examples

### 2.1 Referencing Publications

This statement requires citation [1]; this one is more specific [2, page 162].

### 2.2 Link Examples

This is a URL link: [LaTeX Templates](#). This is an email link: [example@example.com](mailto:example@example.com). This is a monospaced URL link: `https://www.LaTeXTemplates.com`.

### 2.3 Lists

Lists are useful to present information in a concise and/or ordered way.

#### 2.3.1 Numbered List

1. First numbered item
  - a. First indented numbered item
  - b. Second indented numbered item
    - i. First second-level indented numbered item
2. Second numbered item
3. Third numbered item

#### 2.3.2 Bullet Point List

- First bullet point item
  - First indented bullet point item
  - Second indented bullet point item
    - First second-level indented bullet point item
- Second bullet point item
- Third bullet point item

#### 2.3.3 Descriptions and Definitions

**Name** Description

**Word** Definition

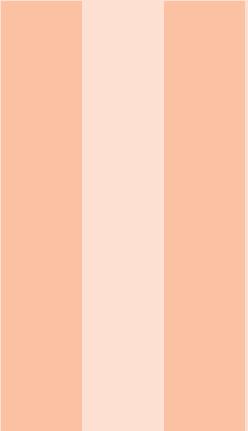
**Comment** Elaboration

## 2.4 International Support

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## 2.5 Ligatures

fi fj fl ffl ffi Ty



# Part Two Title

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## 3. Mathematics

### 3.1 Theorems

#### 3.1.1 Several equations

This is a theorem consisting of several equations.

**Theorem 3.1 — Name of the theorem.** In  $E = \mathbb{R}^n$  all norms are equivalent. It has the properties:

$$|||\mathbf{x}|| - ||\mathbf{y}||| \leq ||\mathbf{x} - \mathbf{y}|| \quad (3.1)$$

$$\left\| \sum_{i=1}^n \mathbf{x}_i \right\| \leq \sum_{i=1}^n \|\mathbf{x}_i\| \quad \text{where } n \text{ is a finite integer} \quad (3.2)$$

#### 3.1.2 Single Line

This is a theorem consisting of just one line.

**Theorem 3.2** A set  $\mathcal{D}(G)$  is dense in  $L^2(G)$ ,  $|\cdot|_0$ .

### 3.2 Definitions

A definition can be mathematical or it could define a concept.

**Definition 3.1 — Definition name.** Given a vector space  $E$ , a norm on  $E$  is an application, denoted  $||\cdot||$ ,  $E$  in  $\mathbb{R}^+ = [0, +\infty[$  such that:

$$||\mathbf{x}|| = 0 \Rightarrow \mathbf{x} = \mathbf{0} \quad (3.3)$$

$$||\lambda \mathbf{x}|| = |\lambda| \cdot ||\mathbf{x}|| \quad (3.4)$$

$$||\mathbf{x} + \mathbf{y}|| \leq ||\mathbf{x}|| + ||\mathbf{y}|| \quad (3.5)$$

### 3.3 Notations

■ **Notation 3.1** Given an open subset  $G$  of  $\mathbb{R}^n$ , the set of functions  $\varphi$  are:

1. Bounded support  $G$ ;
2. Infinitely differentiable;

a vector space is denoted by  $\mathcal{D}(G)$ .

## 3.4 Remarks

This is an example of a remark.



The concepts presented here are now in conventional employment in mathematics. Vector spaces are taken over the field  $\mathbb{K} = \mathbb{R}$ , however, established properties are easily extended to  $\mathbb{K} = \mathbb{C}$ .

## 3.5 Corollaries

**Corollary 3.1 — Corollary name.** The concepts presented here are now in conventional employment in mathematics. Vector spaces are taken over the field  $\mathbb{K} = \mathbb{R}$ , however, established properties are easily extended to  $\mathbb{K} = \mathbb{C}$ .

## 3.6 Propositions

### 3.6.1 Several equations

**Proposition 3.1 — Proposition name.** It has the properties:

$$|||\mathbf{x}|| - ||\mathbf{y}||| \leq ||\mathbf{x} - \mathbf{y}|| \quad (3.6)$$

$$\left\| \sum_{i=1}^n \mathbf{x}_i \right\| \leq \sum_{i=1}^n \|\mathbf{x}_i\| \quad \text{where } n \text{ is a finite integer} \quad (3.7)$$

### 3.6.2 Single Line

**Proposition 3.2** Let  $f, g \in L^2(G)$ ; if  $\forall \varphi \in \mathcal{D}(G)$ ,  $(f, \varphi)_0 = (g, \varphi)_0$  then  $f = g$ .

## 3.7 Examples

### 3.7.1 Equation Example

■ **Example 3.1** Let  $G = \{x \in \mathbb{R}^2 : |x| < 3\}$  and denoted by:  $x^0 = (1, 1)$ ; consider the function:

$$f(x) = \begin{cases} e^{|x|} & \text{si } |x - x^0| \leq 1/2 \\ 0 & \text{si } |x - x^0| > 1/2 \end{cases} \quad (3.8)$$

The function  $f$  has bounded support, we can take  $A = \{x \in \mathbb{R}^2 : |x - x^0| \leq 1/2 + \varepsilon\}$  for all  $\varepsilon \in ]0; 5/2 - \sqrt{2}[$ . ■

### 3.7.2 Text Example

■ **Example 3.2 — Example name.** Aliquam arcu turpis, ultrices sed luctus ac, vehicula id metus. Morbi eu feugiat velit, et tempus augue. Proin ac mattis tortor. Donec tincidunt, ante rhoncus luctus semper, arcu lorem lobortis justo, nec convallis ante quam quis lectus. Aenean tincidunt sodales massa, et hendrerit tellus mattis ac. Sed non pretium nibh. Donec cursus maximus luctus. Vivamus lobortis eros et massa porta porttitor. ■

## 3.8 Exercises

**Exercise 3.1** This is a good place to ask a question to test learning progress or further cement ideas into students' minds. ■

### 3.9 Problems

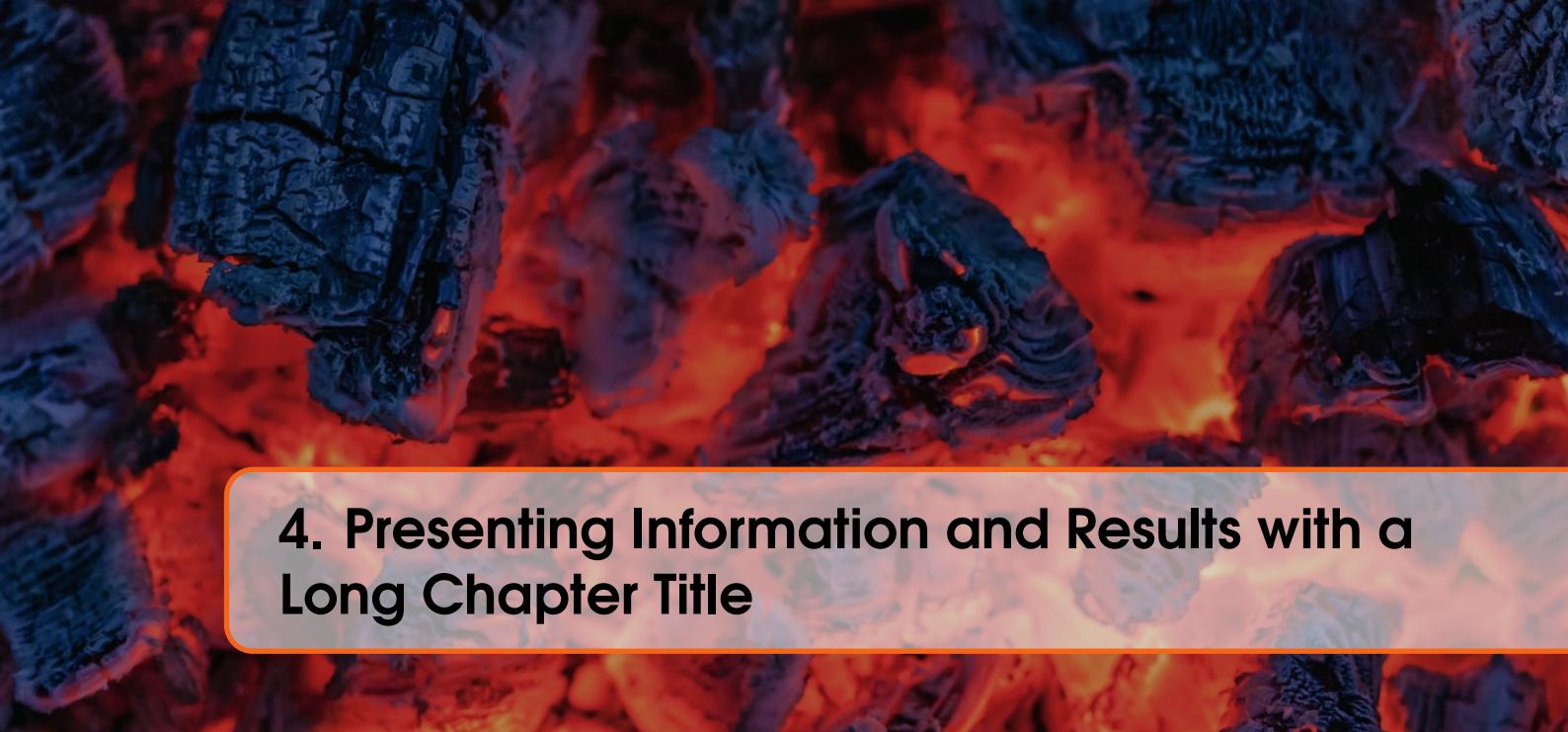
**Problem 3.1** What is the average airspeed velocity of an unladen swallow?

### 3.10 Vocabulary

Define a word to improve a students' vocabulary.

- **Vocabulary 3.1 — Word.** Definition of word.





## 4. Presenting Information and Results with a Long Chapter Title

### 4.1 Table

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Treatments	Response 1	Response 2
Treatment 1	0.0003262	0.562
Treatment 2	0.0015681	0.910
Treatment 3	0.0009271	0.296

Table 4.1: Table caption.

Referencing Table 4.1 in-text using its label.

### 4.2 Figure

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Figure 4.1: Figure caption.

Referencing Figure 4.1 in-text using its label.

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Treatments	Response 1	Response 2
Treatment 1	0.0003262	0.562
Treatment 2	0.0015681	0.910
Treatment 3	0.0009271	0.296

Table 4.2: Floating table.



Figure 4.2: Floating figure.

# Bibliography

## Articles

- [1] A. B. Jones and J. M. Smith. “Article Title”. In: *Journal title* 13.52 (Mar. 2022), pages 123–456. DOI: [10.1038/s41586-021-03616-x](https://doi.org/10.1038/s41586-021-03616-x) (cited on page 13).

## Books

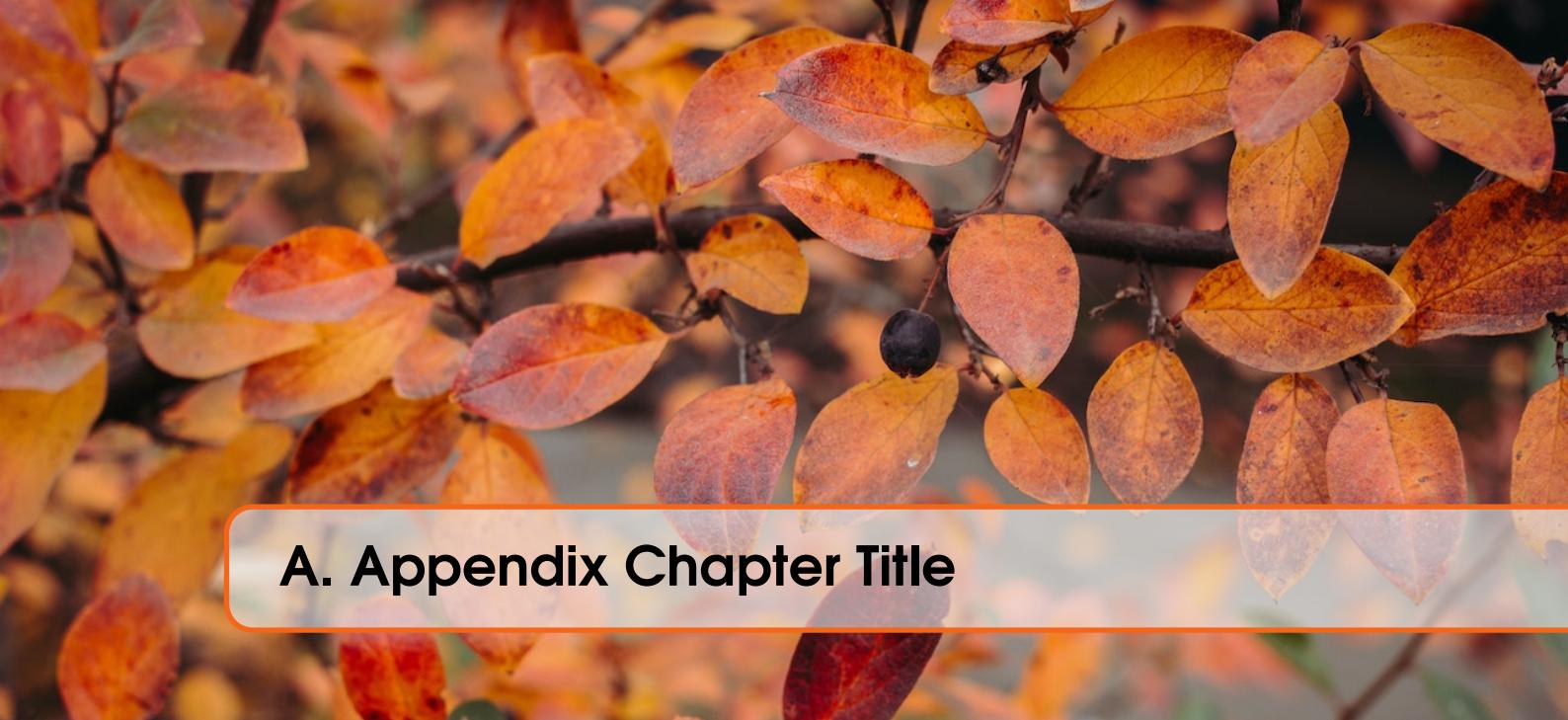
- [2] J. M. Smith and A. B. Jones. *Book Title*. 7th. Publisher, 2021 (cited on page 13).



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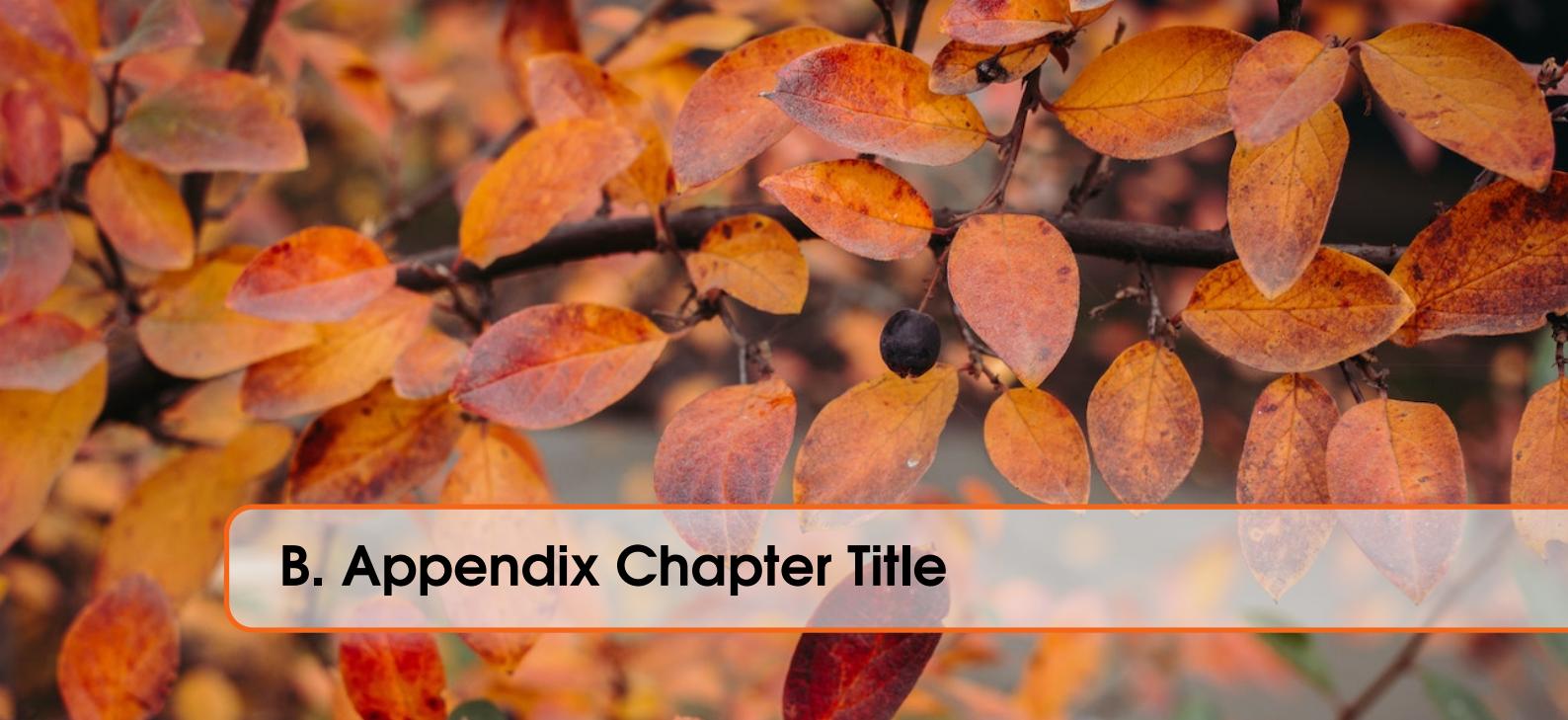


## A. Appendix Chapter Title

### A.1 Appendix Section Title

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## B. Appendix Chapter Title

### B.1 Appendix Section Title

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