Signal Processing

Introduction to LaTeX

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Outline

What is LaTeX?

- LaTeX is a document preparation system.
- It's not a word processor - you describe content using plain text.
- Produces high-quality, consistent typesetting, ideal for:
  - Scientific papers, reports, theses
  - Presentations (like this one!)
  - CVs and resumes

Why Use LaTeX?

- Separates content from formatting
- Handles math beautifully
- Built-in references, citations, and lists
- Fully reproducible: just share the .tex file
- Industry and academia standard in engineering fields

Installing LaTeX

Linux:

- Install via package manager:
  `sudo apt install texlive-full`

Windows:

- Install `MiKTeX`

Mac:

- Install `MacTeX`

Popular Editors

Overleaf:

- Cloud-based LaTeX editor — no installation needed.
- Great for collaboration and templates.

VS Code:

- Install `LaTeX Workshop` extension.
- Works offline

Your First Document

Code

```
\documentclass{article}
\begin{document}
Hello, world! This is my first LaTeX document.
\end{document}
```

Compile using: `pdflatex filename.tex`

Document Structure

```
\documentclass{article}
\usepackage{amsmath}

\begin{document}

\section{Task}
You can organize your document in sections.

\subsection{Subtask}
You can organize each section with subsections.

\end{document}
```

Text and Formatting

```
\textbf{Bold}, \textit{italic}, \underline{underline}
% This is a comment
```

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% This is a comment
```

Bold text, *italic*, underline
Comments start with %.

Figures

```
\begin{figure}[h]
  \centering
  \includegraphics[width=0.7\textwidth]{image.png}
  \caption{Example figure.}
  \label{fig:example}
\end{figure}
```

Figures

Figure: Example figure with caption

You can create a reference to a figure or a table using

```
\ref{fig:example}
```

This is my reference to the sample figure 1.

Lists

Lists:

```
\begin{itemize}
  \item Item 1
  \item Item 2
\end{itemize}
```

Lists

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```

Lists:

- Item 1
- Item 2

Lists

Numbered List:

```
\begin{enumerate}
  \item Item 1
  \item Item 2
\end{enumerate}
```

Lists

Numbered List:

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\begin{enumerate}
  \item Item 1
  \item Item 2
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```

Numbered List:

1. Item 1
2. Item 2

Tables

Tables:

```
\begin{tabular}{lc}
Signal & Mean \\
\hline
$x[n]$ & 0.5 \\
$y[n]$ & 0.3 \\
\end{tabular}
```

Tables

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Signal & Mean \\
\hline
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Tables:

Signal	Mean
$x[n]$	0.5
$y[n]$	0.3

Math Basics

Inline math: `$a^2 + b^2 = c^2$` → $a^2 + b^2 = c^2$

Display math:

```
\[
E = mc^2
\]
```

$$E = mc^2$$

Signal Processing Examples

Convolution (1D continuous):

```
\[
y(t) = (x * h)(t)
     = \int_{-\infty}^{\infty} x(\tau) h(t-\tau) d\tau
\]
```

$$y(t) = (x * h)(t) = \int_{-\infty}^{\infty} x(\tau)h(t-\tau)d\tau$$

Convolution (1D Discrete):

```
\[
y[k] = (x * h)[k]
     = \sum_{m=-\infty}^{\infty} x[m] h[k-m]
\]
```

$$y[k] = (x * h)[k] = \sum_{m=-\infty}^{\infty} x[m]h[k-m]$$

Signal Processing Examples

Fourier Transform (continuous-time)

```
\[
X(\omega) =
\int_{-\infty}^{\infty} x(t) e^{-j \omega t} dt
\]
```

$$X(\omega) = \int_{-\infty}^{\infty} x(t)\, e^{-j\omega t}\, dt$$

Discrete-Time Fourier Transform (DTFT)

```
\[
X(e^{j\omega}) =
    \sum_{k=-\infty}^{\infty} x[k] e^{-j\omega k}
\]
```

$$X(e^{j\omega}) = \sum_{k=-\infty}^{\infty} x[k]e^{-j\omega k}$$

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$$X(e^{j\omega}) = \sum_{k=-\infty}^{\infty} x[k] e^{-j\omega k}$$

```
\omega \in [-\pi, \pi]
```

$\omega \in [-\pi, \pi]$

Where to Learn More

- Overleaf - Learn LaTeX in 30 Minutes
- Overleaf - Mathematical expressions
- A simple guide to LaTeX

Questions?

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Inline vs Display Math

In LaTeX, math can appear:

- **Inline:** inside text, with single \$ symbols.
- **Display:** centered on its own line, with double \$\$ or \[...\].

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Example Code

```
Inline: $y = x + \eta$
Display:
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\boldsymbol{y} = \boldsymbol{x} + \boldsymbol{\eta}
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```

Rendered Output

Inline: $y = x + \eta$ Display:

$$\boldsymbol{y} = \boldsymbol{x} + \boldsymbol{\eta}$$

Bold Symbols and Greek Letters

Use \boldsymbol for vectors and matrices.

Example Code

```
\[
\boldsymbol{x},\; \boldsymbol{y},\; \boldsymbol{\eta},\;
\lambda,\; \sigma,\; \mathbb{R}^n
\]
```

Bold Symbols and Greek Letters

Use \boldsymbol for vectors and matrices.

Example Code

```
\[
\boldsymbol{x},\; \boldsymbol{y},\; \boldsymbol{\eta},\;
\lambda,\; \sigma,\; \mathbb{R}^n
\]
```

Rendered Output

$$\boldsymbol{x},\ \boldsymbol{y},\ \boldsymbol{\eta},\ \lambda,\ \sigma,\ \mathbb{R}^n$$

Fractions, Superscripts, and Subscripts

LaTeX supports mathematical structure like powers and indices.

Example Code

```
\[
\hat{\boldsymbol{x}}_i = \frac{x_i + y_i}{2}, \qquad
E = mc^2
\]
```

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Rendered Output

$$\hat{\boldsymbol{x}}_i = \frac{x_i + y_i}{2}, \qquad E = mc^2$$

Matrices and Operators

Use the `bmatrix` environment for matrices.

Example Code

```
\[
\boldsymbol{D} =
\begin{bmatrix}
-1 & 1 & 0 \\
0 & -1 & 1
\end{bmatrix}
\]
```

Matrices and Operators

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\]
```

Rendered Output

$$\boldsymbol{D} = \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix}$$

Norms and Optimization Problems

Useful for signal estimation and inverse problems.

Example Code

```
\[
\min_{\boldsymbol{x}\in\mathbb{R}^n}
\|\boldsymbol{x} - \boldsymbol{y}\|_2^2
+ \lambda \|\boldsymbol{D}\boldsymbol{x}\|_1
\]
```

Norms and Optimization Problems

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Rendered Output

$$\min_{\boldsymbol{x}\in\mathbb{R}^n} \|\boldsymbol{x} - \boldsymbol{y}\|_2^2 + \lambda \|\boldsymbol{D}\boldsymbol{x}\|_1$$

Piecewise Functions

Use the cases environment for definitions.

Example Code

```
\[
R(\boldsymbol{x}) =
\begin{cases}
\|\boldsymbol{D}\boldsymbol{x}\|_2^2, & \text{L2 regulariza
\|\boldsymbol{D}\boldsymbol{x}\|_1, & \text{TV regularizati
\end{cases}
\]
```

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```

Rendered Output

$$R(\boldsymbol{x}) = \begin{cases} \|\boldsymbol{D}\boldsymbol{x}\|_2^2, & \text{L2 regularization,} \\ \|\boldsymbol{D}\boldsymbol{x}\|_1, & \text{TV regularization.} \end{cases}$$

Text Inside Math Mode

Use \text{} for explanations inside equations.

Example Code

```
\[
\min_{\boldsymbol{x}}
\underbrace{\|\boldsymbol{x} - \boldsymbol{y}\|_2^2}_{\text
+ \lambda
\underbrace{\|\boldsymbol{D}\boldsymbol{x}\|_1}_{\text{regu
\]
```

Text Inside Math Mode

Use \text{} for explanations inside equations.

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```
\[
\min_{\boldsymbol{x}}
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+ \lambda
\underbrace{\|\boldsymbol{D}\boldsymbol{x}\|_1}_{\text{regu
\]
```

Rendered Output

$$\min_{\boldsymbol{x}} \underbrace{\|\boldsymbol{x} - \boldsymbol{y}\|_2^2}_{\text{data fidelity}} + \lambda \underbrace{\|\boldsymbol{D}\boldsymbol{x}\|_1}_{\text{regularization}}$$

Putting It All Together

Example Code

```
\[
\text{MSE}(\tilde{\boldsymbol{x}}, \boldsymbol{x})
= \frac{1}{n}\sum_{i=1}^n (\tilde{x}_i - x_i)^2
\]
```

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