

<!-- SOURCE_FILE:
/Users/hari/Desktop/sandbox/md2pdf/examples/academic_paper/paper.md -->

A Unified Framework for Programmatic Document Generation

Abstract: We present a lightweight, fast, and dependency-free method for compiling structured Markdown documents directly into print-ready PDF files. Unlike conventional approaches that rely on heavy web rendering engines (e.g., headless Chromium) or extensive CLI wrappers (e.g., Pandoc and LaTeX), our engine leverages a direct compiler pipeline from a Python-based Markdown Abstract Syntax Tree (AST) straight to ReportLab flowables. We explore performance characteristics, typesetting rules, and the integration of mathematical notation and vector diagrams.

1. Introduction

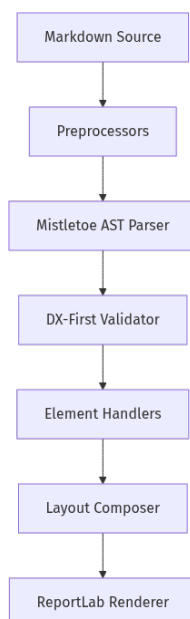
Document processing systems traditionally fall into two categories:

- 1 **Interactive wysiwyg editors**, which are prone to styling inconsistencies and lack programmatic extensibility.
- 2 **Markup languages** like $L^A_T E X$ or HTML/CSS, which require massive software distributions or depend on heavy browser engine runtimes.

We introduce a middle ground: **programmatic Markdown compilation**. By leveraging a parser to build a robust AST, we map structural tokens directly to programmatic layout elements (flowables).

2. Pipeline Architecture

The compiler operates in four distinct phases: pre-processing, parsing/validation, element mapping, and layout composition. The diagram below illustrates this linear data flow:



3. Mathematical Notation

Mathematical statements are parsed from standard L^AT_EX notation. Single dollar signs denote inline math such as $f(x) = \sin(x) \cdot e^{-x^2}$. Display or block math uses double dollar signs:

$$\oint_C \mathbf{B} \cdot d\mathbf{l} = \mu_0 \left(I_{\text{enc}} + \varepsilon_0 \frac{d\Phi_E}{dt} \right)$$

These equations are automatically pre-fetched in parallel and cached using SHA-256 hashes of their raw LaTeX strings to prevent redundant network round-trips¹.

4. Empirical Evaluation

To measure the rendering speed, we compared our engine against a headless Chromium browser wrapper across documents of various sizes.

Page Count	Headless Chrome (sec)	md2pdf (sec)	Speedup Ratio
5 pages	2.45	0.18	13.61×
20 pages	3.12	0.45	6.93×
100 pages	7.84	1.89	4.15×

As shown in the table above, the compilation overhead of our engine is significantly lower, making it ideal for high-throughput automated report generation.

¹ Caching is performed in the local user cache directory (e.g., ~/.cache/pymd2pdf) and supports offline fallbacks.

5. Conclusions

By eliminating the browser-level dependency, programmatic document compilation achieves substantial performance gains while maintaining rigorous typesetting rules such as orphaned heading prevention and dynamic page-breaking logic².

² Layout composer rules ensure that tables split cleanly across page boundaries and repeat headers on subsequent pages automatically.