INFORMATION MODELS FOR PREDICTION

PROJECT 1 - ALGORITHMIC THEORY OF INFORMATION COURSE

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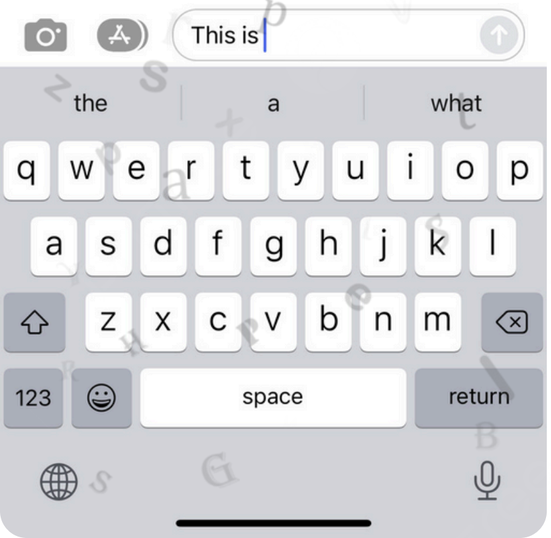


Introduction

- Implemented Finite-Context Models (FCMs) for text analysis and predictive text generation.
- **Aim:** Estimate symbol distributions in text for statistical analysis and predictive text generation.
- Developed two main C++ programs:
  - **fcm** (statistical analysis)
  - **generator** (text generation)
- Evaluated models performance with varying parameters (context order *k*, smoothing *alpha*).
- Implemented and compared JSON/binary model export formats.

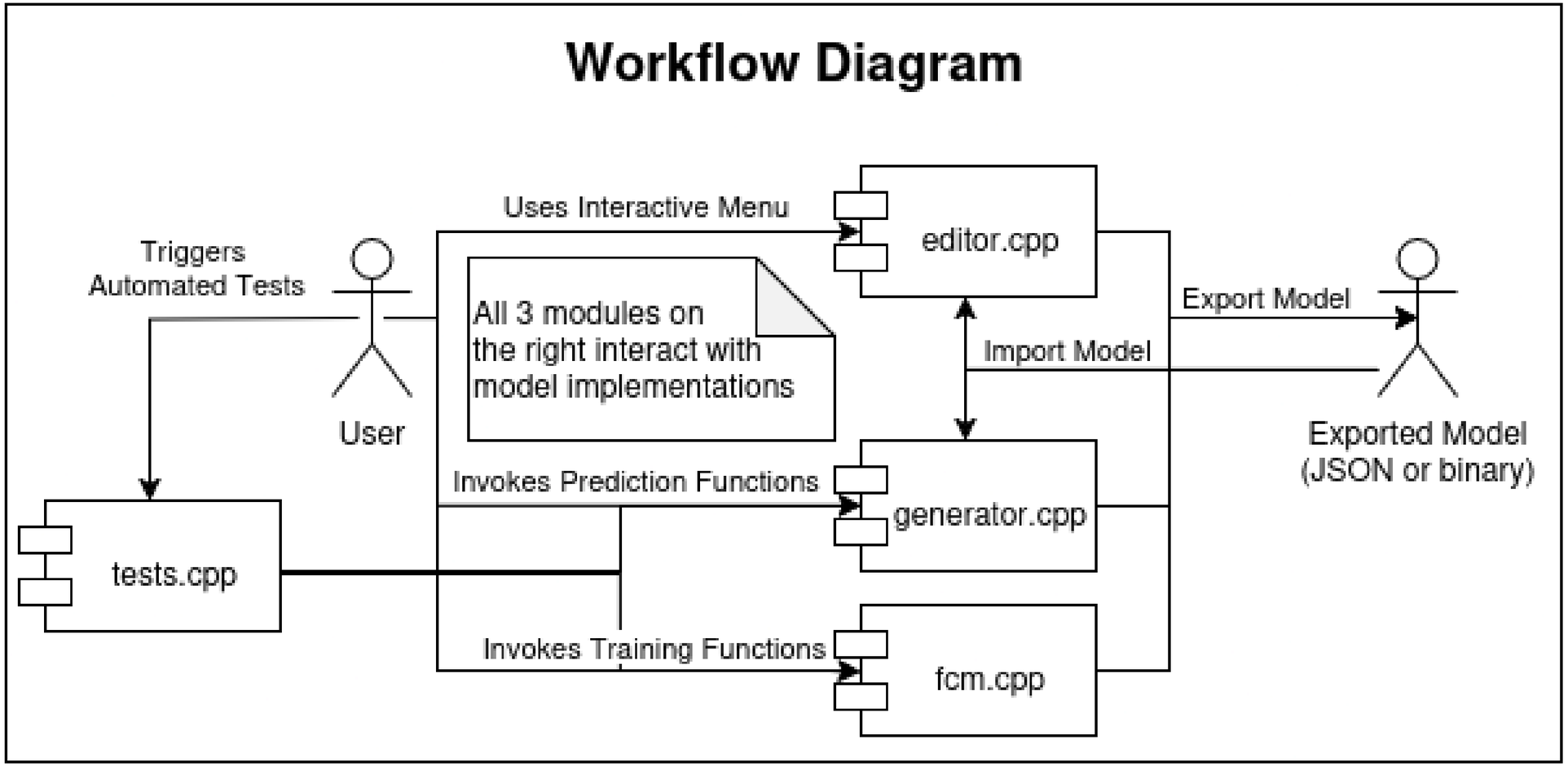
Key Programs Developed

fcm:
Reads input text, constructs FCM by updating frequency tables, computes probabilities with Laplace smoothing, calculates Average Information Count.

generator:
Generates new text based on a trained model using weighted random selection and can also do all operations **fcm** does.

editor:
User-friendly interactive text-based interface for model manipulation.

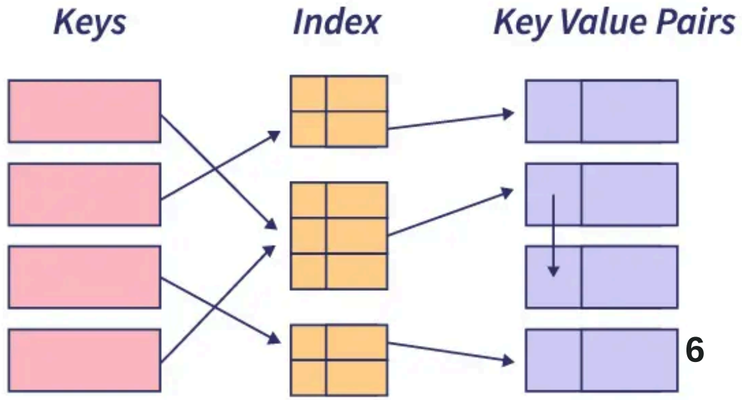
tests:
Automated testing, with multiple combination of parameters, for models validation.


Workflow Diagram
Uses Interactive Menu
editor.cpp
Triggers
Automated Tests
User
All 3 modules on
the right interact with
model implementations
Export Model
Import Model
Exported Model
(JSON or binary)
Invokes Prediction Functions
generator.cpp
tests.cpp
Invokes Training Functions
fcm.cpp

Model Implementation

Data Structures

- **Hash Tables** (*unordered_map*) for efficient O(1) lookups.
- **Frequency Table:** counts occurrences of symbols after contexts.
- **Context Count Table:** tracks context occurrences.
- **Probability Table:** stores computed probabilities.
- **Alphabet Set:** stores unique symbols.



Implementation Steps

Learning Phase

- UTF-8 character splitting.
- Sliding window processing.
- Dynamic alphabet update.
- Context frequency updating.
- Probability computation with Laplace smoothing.

Average Information Content Calculation

- Quantifies the model quality (lower == better)
- Measured in bits per symbol (bps)

Text Generation

- Context-based sampling.
- Weighted random selection via cumulative distribution.
- Rolling context updates.

Standard FCM vs Recursive FCM

Standard FCM

Uses fixed context length k

Recursive FCM

Incorporates multiple context lengths (*k* down to 1).

RFCM features:

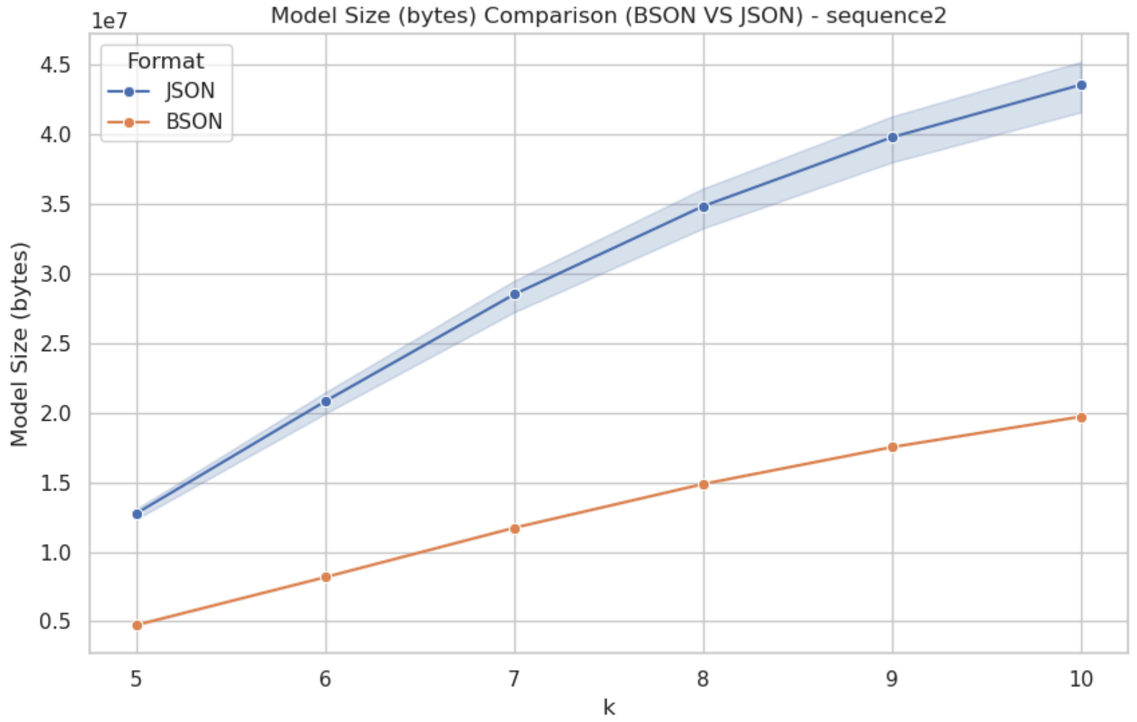
- Recursive learning for all context lengths.
- Separate frequency tables for each context length.
- Recursive probability retrieval with fallback mechanism.

Model Export/Import

{JSON} VS {01010100 11101011 10101110 01010101} BSON

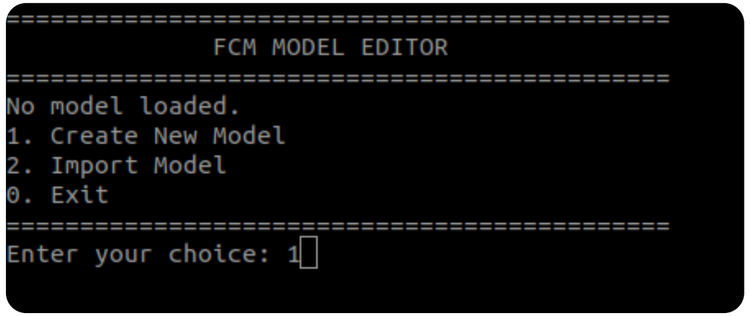
Formats

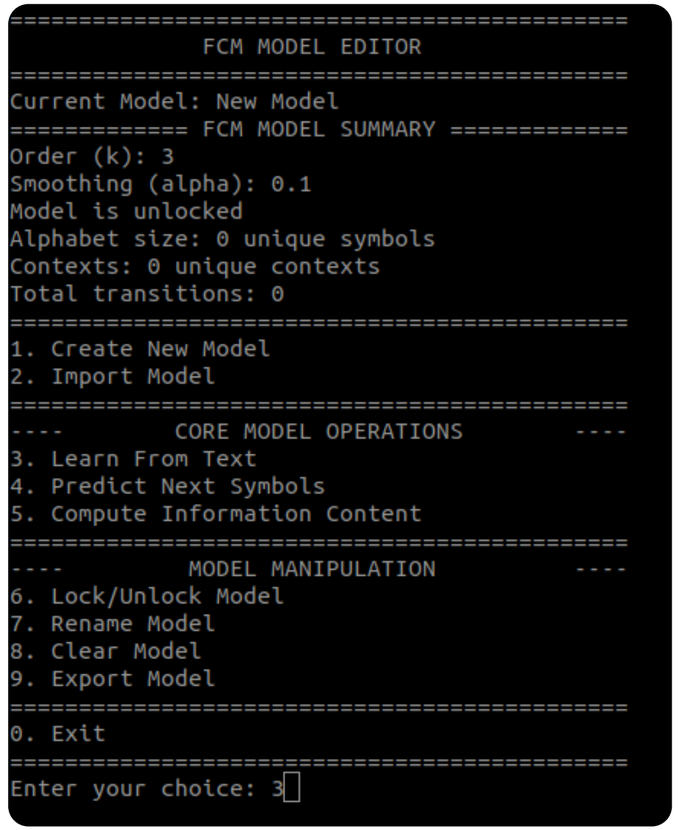
- **JSON:**
  - Human-readable.
  - Larger file size.
- **Binary (BSON):**
  - Compact & Efficient.
  - Non-human readable.



Editor and Auxiliary Features

- Interactive menu for model creation and manipulation.
- Models properties display.
- Continuous refinement.
- Syntactic analysis via word list comparison.





Generated Text Samples

- Example outputs with different parameters.
- Syntactic validation evaluation (in this example, ~75% of the words were recognized).

```
Enter the context to predict from: porta
Enter the number of symbols to predict: 200
Starting prediction with context: 'porta'
Context has 5 characters, model k=5
Using rolling context: 'porta'
Prediction:
 o mar aparece toda Frandecerá desbarata
Inda não cego enganosas se parece que esse a tanto menos de Anfitrite deleito,
Pelo neto de tão dirá que tenro a espanto
Que tão fizerem ao mesta, por que tant

==========================================
Do you want to perform a syntactic analysis? (y/n): y
Enter the filename to load the word list from: syntactic_analysis/ptWords.txt
Read 13929038 characters from syntactic_analysis/ptWords.txt
Syntactic Analysis Results:
Total words in prediction: 37
Valid words in prediction: 28
Percentage of valid words: 75.6757%
```

Experimental Results

Effect of Context Size

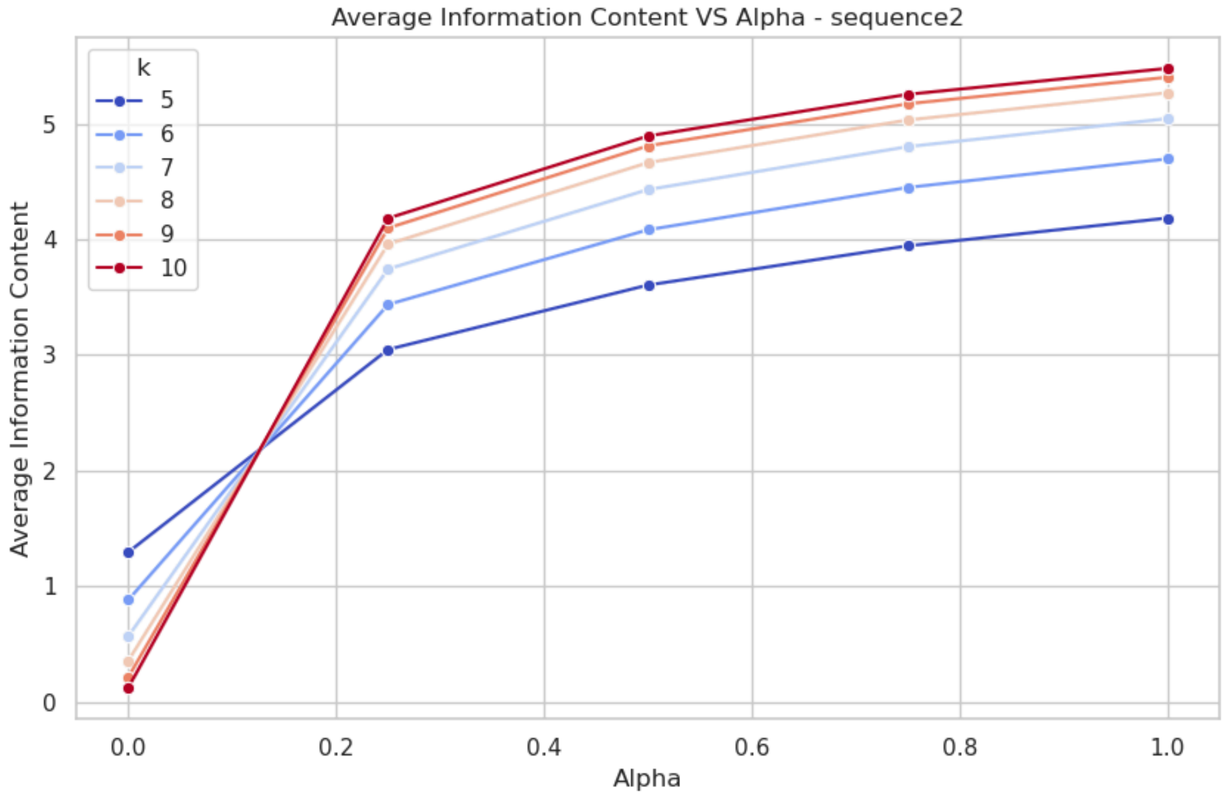
Context Size k	Average Information Content (bits per symbol)
1	3.34668
3	2.4112
5	2.41512
10	3.14763
30	3.24091

Average Information Content, based on k - sequence2.txt

Experimental Results

Impact of Smoothing Parameter

- Moderate *alpha* values generally produce more reliable models.
- Need to balance over-smoothing and under-smoothing.

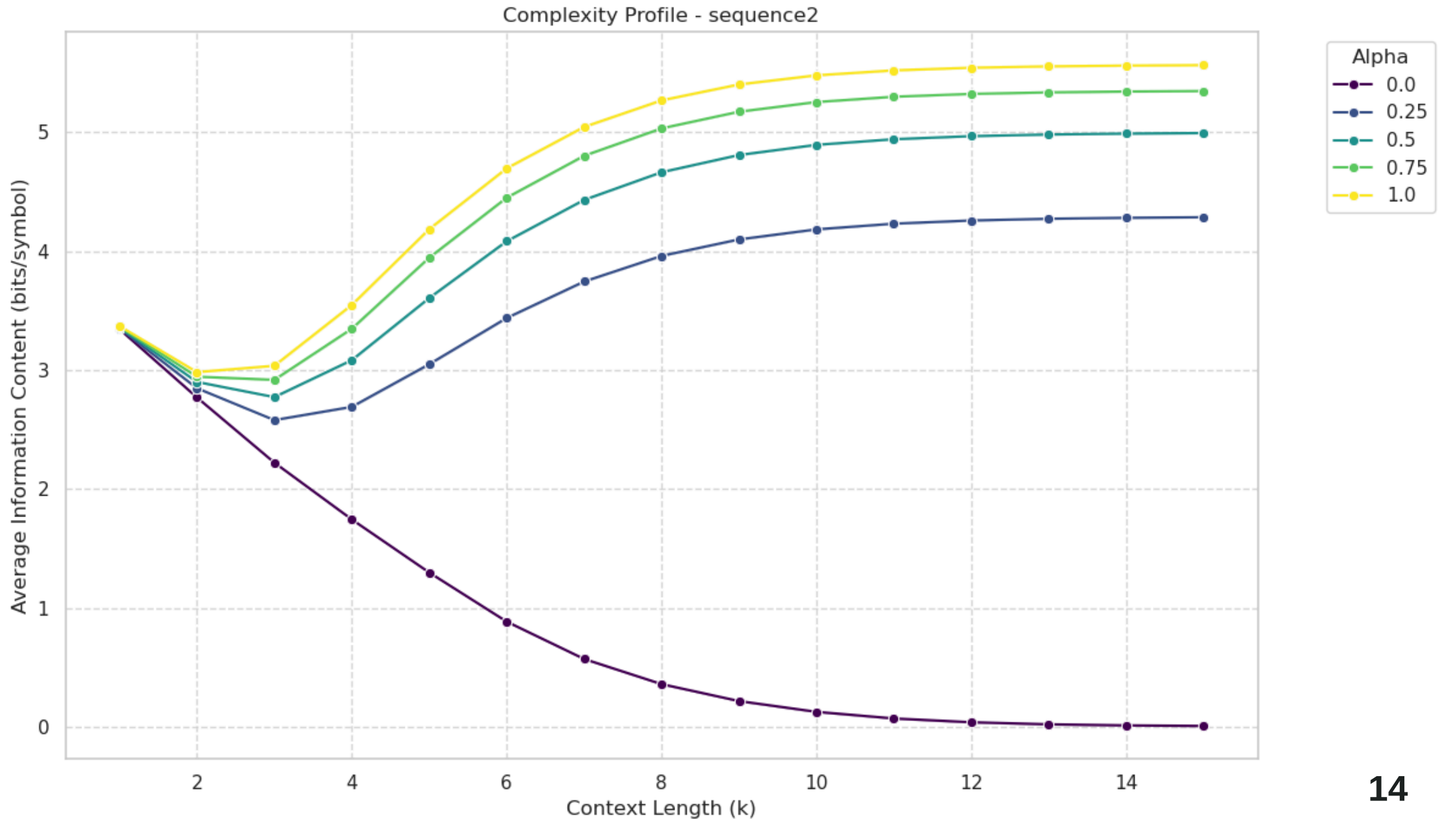


Average Information Content, based on alpha – sequence2.txt

Experimental Results

Complexity Profiles

- Lower-order contexts contribute significantly to prediction accuracy.
- Sharp decreases at low *alpha* values indicate highly structured sequences.
- Higher *alpha* values show more randomness and long-range dependencies



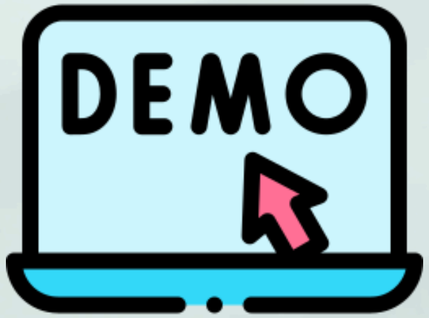
Complexity Profile - sequence2.txt

Main Findings

- Optimal context size (k) between 3-5 for tested datasets.
- Moderate smoothing parameters (~0.1) produce more reliable models.
- Binary serialization reduced storage by 40-60% compared to JSON.
- Generated text exhibited recognizable stylistic elements.
- Syntactic analysis showed moderate-high rate of valid words.

Future Work

- Adaptive context selection based on pattern availability.
- Enhanced dictionary integration for linguistic coherence.
- Interactive text generation with real-time suggestions.
- Improved dictionary-based correction mechanisms.



LIVE DEMO

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QUESTIONS