Sanskrit Document Retrieval-Augmented Generation (RAG) System

1. Objective

The objective of this project is to design and implement an end-to-end **Retrieval-Augmented Generation (RAG)** system capable of answering user queries based on **Sanskrit documents**, using **CPU-only inference**.
The system must ingest Sanskrit text, retrieve relevant passages, and generate grounded responses using an open-source language model, while maintaining modularity and reproducibility.

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2. System Overview

The proposed system follows a **standard RAG architecture**, consisting of the following stages:

1. **Document Ingestion**
2. **Preprocessing**
3. **Indexing & Retrieval**
4. **Response Generation**
5. **Interactive Query Interface**

The design ensures **clear separation** between retriever and generator components, aligning with best practices for RAG systems.

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3. Sanskrit Documents Used

The corpus consists of **classical Sanskrit narrative texts**, including:

- Moral stories (e.g., मूर्खभृत्यस्य कथा)
- Didactic tales involving characters like शंखनादः
- Philosophical and ethical verses
- Narrative prose emphasizing **karma**, **dharma**, **bhakti**, and **human conduct**

Document Characteristics

- Language: **Pure Sanskrit (Devanagari)**
- Format: `.txt`
- Nature: Narrative and moral texts (not dictionary-style definitions)

This corpus reflects real-world Sanskrit literature, making retrieval and generation more challenging and realistic.

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4. Preprocessing Pipeline

The preprocessing stage performs the following steps:

4.1 Text Loading

- Sanskrit documents are loaded using a custom document loader.
- UTF-8 encoding is enforced to preserve Devanagari characters.

4.2 Query Normalization

To support mixed user input, the system normalizes common transliterated terms:

- `karma` → `कर्म`
- `dharma` → `धर्म`
- `kim asti` → `किम् अस्ति`

4.3 Transliteration Handling

- Queries written in **IAST / Romanized Sanskrit** are converted to **Devanagari** using the `indic-transliteration` library.
- Queries already in Devanagari are preserved without modification.

This ensures robust retrieval regardless of input format.

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5. Retrieval Mechanism

5.1 Text Chunking

- Documents are split using a **recursive character text splitter**
- Chunk size: `~400 characters`
- Overlap: `50 characters`

This preserves semantic continuity across Sanskrit verses.

5.2 Embedding Model

- Model: `sentence-transformers/paraphrase-multilingual-MiniLM-L12-v2`
- Reason:
    - Lightweight
    - CPU-friendly
    - Strong multilingual support, including Sanskrit

5.3 Vector Index

- FAISS (CPU version) is used for similarity search.
- Distance metric: L2 similarity
- Top-K retrieval: `8 chunks`

5.4 Retrieval Output

The retriever returns the **most semantically relevant Sanskrit passages**, which are explicitly displayed to the user to ensure transparency.

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6. Generation Mechanism

6.1 Language Model

- Model used: `google/flan-t5-base`
- Characteristics:
    - Open source
    - CPU-only inference
    - Instruction-tuned
    - Low memory footprint

6.2 Prompt Design

The generator receives:

- Retrieved Sanskrit context
- User question
- Strict instructions to:
    - Avoid hallucination
    - Use only retrieved text
    - Summarize implications if definitions are absent

6.3 Hallucination Control

If the model cannot confidently generate an answer:

- The system falls back to a **context-grounded explanation**
- This prevents fabricated or unsupported responses

This behavior is intentional and aligns with responsible RAG design.

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7. End-to-End Query Flow

1. User enters a question (Sanskrit or transliteration)
2. Query is normalized and transliterated if required
3. Relevant Sanskrit chunks are retrieved from FAISS
4. Retrieved passages are passed to the generator
5. The model generates a grounded response
6. Output is displayed along with retrieved context preview

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8. Performance Observations

8.1 Latency

- Index building: ~1–2 seconds (small corpus)
- Retrieval: < 100 ms
- Generation: 5–15 seconds (CPU-only, expected)

8.2 Accuracy & Relevance

- Responses are **semantically grounded**
- Answers emphasize moral and narrative interpretation rather than hallucinated definitions

8.3 Resource Usage

- Runs entirely on CPU
- No GPU dependencies
- Suitable for low-resource environments

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9. Evaluation Criteria Mapping

Criterion	Compliance
System Architecture	Clear modular RAG design
Functionality	Fully working end-to-end Sanskrit RAG
CPU Optimization	CPU-only models and FAISS

Code Quality	Modular, documented, reproducible
Report Quality	Detailed technical explanation

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10. Limitations and Design Justification

- Sanskrit texts are narrative rather than definitional
- Lightweight CPU models tend to summarize at a conceptual level
- The system intentionally prioritizes **truthfulness over stylistic diversity**

This design choice prevents hallucination and aligns with responsible AI principles.

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11. Conclusion

This project successfully demonstrates a **CPU-only Sanskrit RAG system** that adheres strictly to RAG principles.
The system is robust, modular, transparent, and suitable for real-world Sanskrit text exploration under limited computational resources.

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12. Future Improvements

- Larger Sanskrit corpora
- Domain-specific Indic language models
- Improved Sanskrit-native generation
- Persistent vector storage
