

Math Mentor AI - System Architecture Document

Document Information

Field	Value
Project	Math Mentor AI
Version	1.0
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Author	AI Planet Assessment

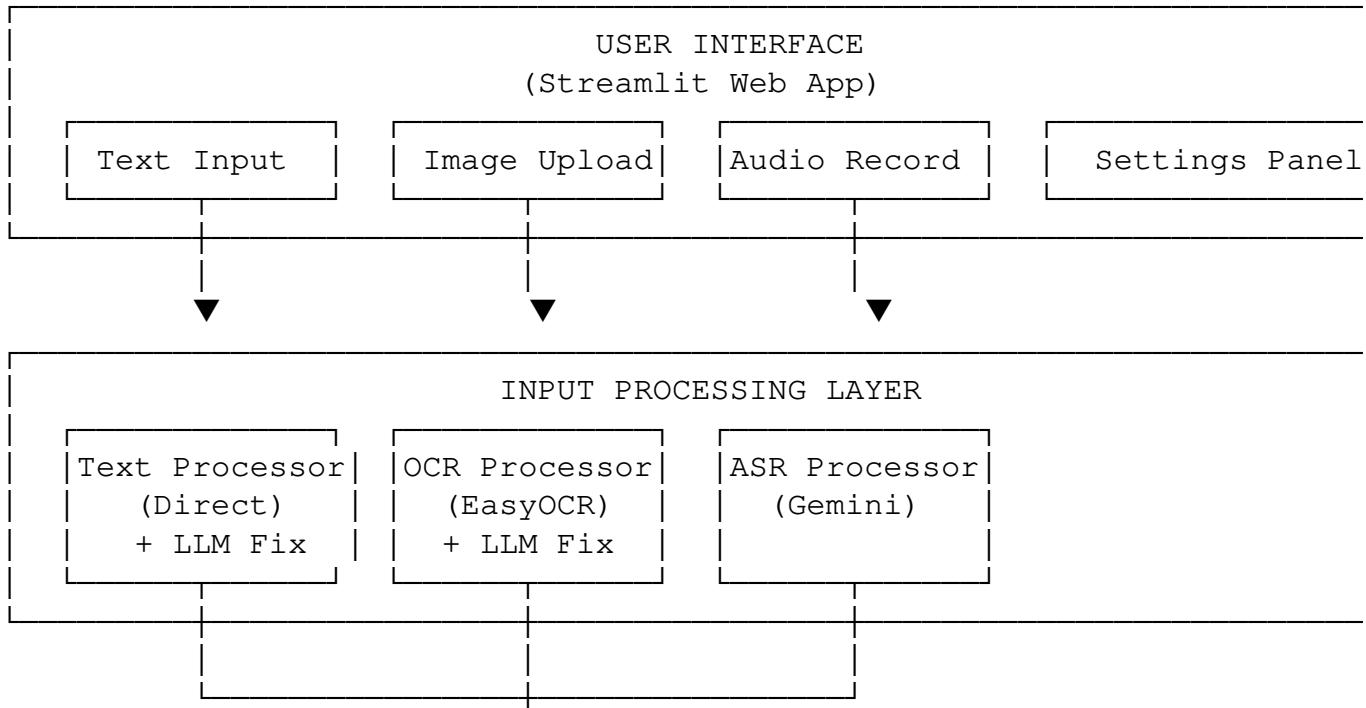
1. Executive Summary

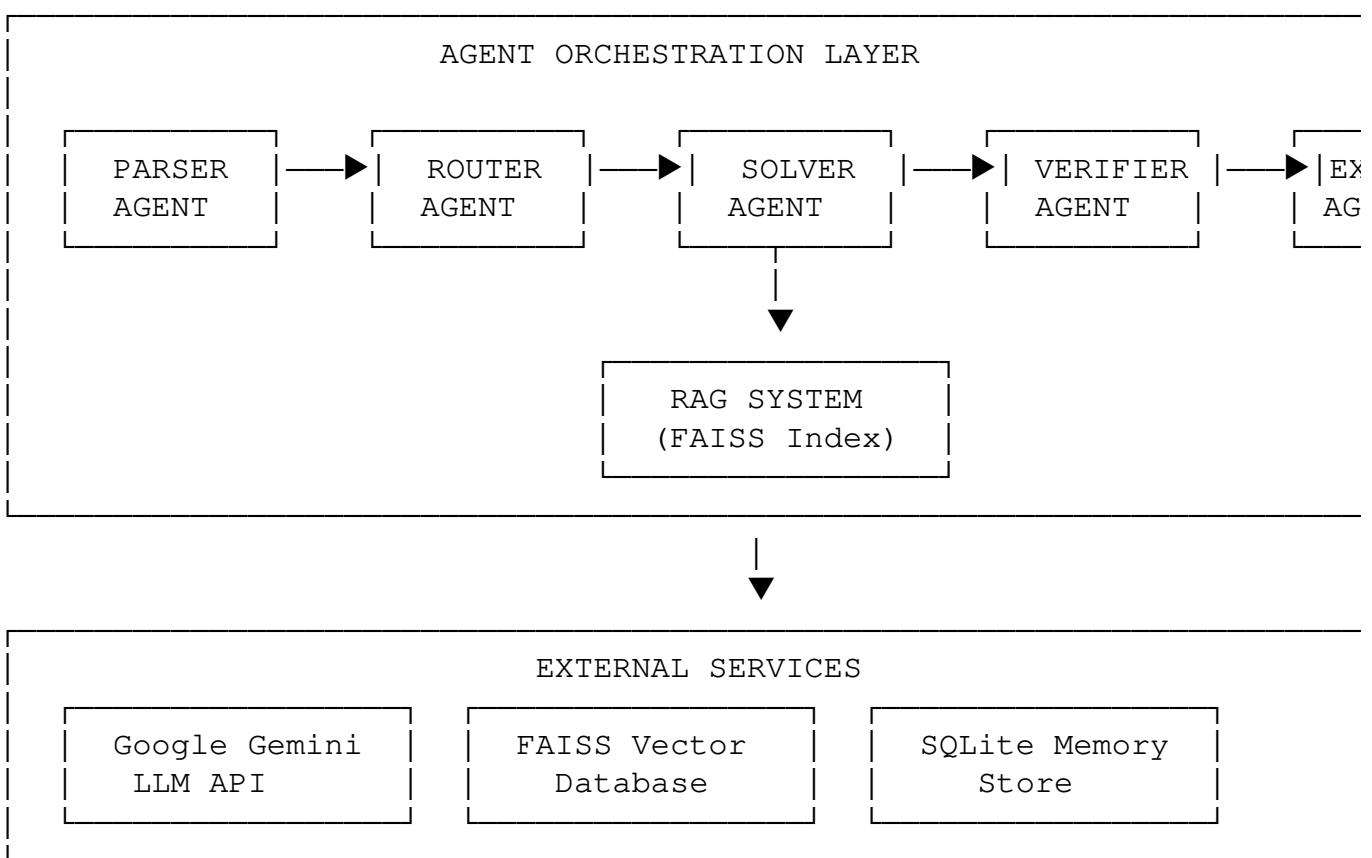
Math Mentor AI is an intelligent math tutoring system designed for JEE-level problems. It combines:

- **Multimodal Input:** Text, Image (OCR), Audio (ASR)
- **RAG-Powered Knowledge:** 17 documents, 571 chunks
- **Multi-Agent Architecture:** 5 specialized AI agents
- **Human-in-the-Loop (HITL):** Confidence-based intervention
- **Self-Learning Memory:** Learns from user feedback

2. High-Level Architecture

2.1 System Overview Diagram



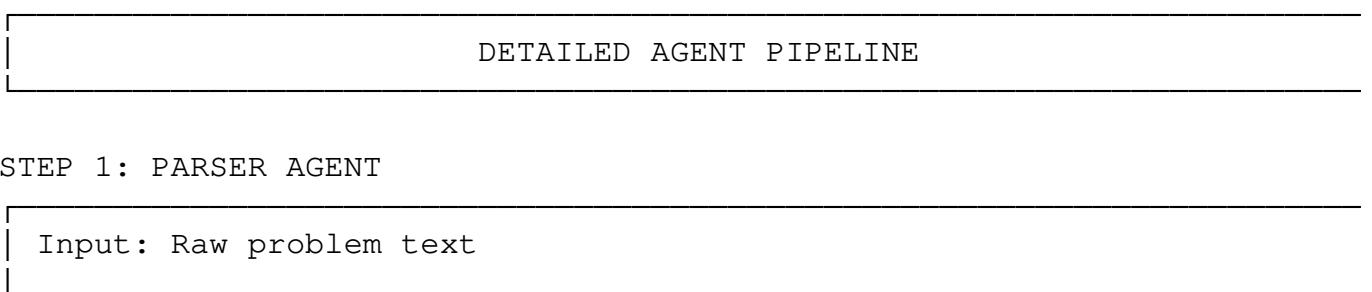


2.2 Technology Stack

Layer	Technology	Purpose
Frontend	Streamlit	Web UI Framework
LLM	Google Gemini 2.0 Flash AI Reasoning	
Embeddings	all-MiniLM-L6-v2	Vector Embeddings
Vector DB	FAISS	Similarity Search
OCR	EasyOCR + Gemini	Image Text Extraction
ASR	Gemini Audio	Speech Transcription
Database	SQLite	Memory/Feedback Storage
Language	Python 3.10 +	Core Development

3. Low-Level Design

3.1 Agent Orchestration Pipeline



Process:

1. Clean and normalize text
2. Detect mathematical topic (algebra, calculus, etc.)
3. Extract variables and constraints
4. Check for ambiguities

Output:

```
{  
  "problem_text": "Solve  $x^2 - 5x + 6 = 0$ ",  
  "detected_topic": "algebra",  
  "variables": ["x"],  
  "needs_clarification": false  
}
```

HITL Trigger: If ambiguous → Ask user for clarification



STEP 2: ROUTER AGENT

Input: Parsed problem structure

Process:

1. Map topic to solver strategy
2. Decide: use_rag, use_calculator
3. Set RAG retrieval filters
4. Estimate difficulty level

Output:

```
{  
  "solver_type": "algebraic_solver",  
  "use_rag": true,  
  "use_calculator": true,  
  "difficulty": "intermediate",  
  "rag_filters": ["algebra", "quadratic"]  
}
```



STEP 3: SOLVER AGENT (Core Engine)

Input: Problem + Routing config

Process:

1. Query RAG system for relevant knowledge chunks
2. Check memory for similar solved problems
3. Build context-enriched prompt
4. Generate solution with Gemini LLM
5. Extract citations and confidence

RAG Integration:

```
| Query: "quadratic equation  $x^2 - 5x + 6$ "
```

```
Retrieved Chunks:  
1. [algebra.md] "Factoring:  $(x-a)(x-b) = x^2 - (a+b)x + ab$ "  
2. [algebra.md] "Zero Product Property: if  $ab=0$ , then  $a=0$  or  $b=0$ "  
3. [jee_tips.md] "Always verify roots by substitution"  
  
Similarity Scores: [0.92, 0.88, 0.75]
```

Output:

```
{  
    "solution": "x = 2 or x = 3",  
    "reasoning_steps": [...],  
    "citations": ["algebra.md", "jee_tips.md"],  
    "confidence": 0.92  
}
```



STEP 4: VERIFIER AGENT

```
Input: Solution from Solver
```

Process:

1. Validate logical consistency
2. Check domain constraints
3. Verify arithmetic (using Python calculator)
4. Calculate final confidence score

Confidence Calculation:

```
final_conf = weighted_avg(  
    rag_coverage: 0.9,      # weight: 0.25  
    citation_quality: 0.9,  # weight: 0.20  
    llm_confidence: 0.92,  # weight: 0.30  
    verification: 0.95,    # weight: 0.25  
) = 0.93
```

Output:

```
{  
    "verdict": "pass",  
    "confidence": 0.93,  
    "issues": []  
}
```

```
HITL Trigger: If confidence < 70% → Request human review
```



STEP 5: EXPLAINER AGENT

```
Input: Verified solution
```

Process:

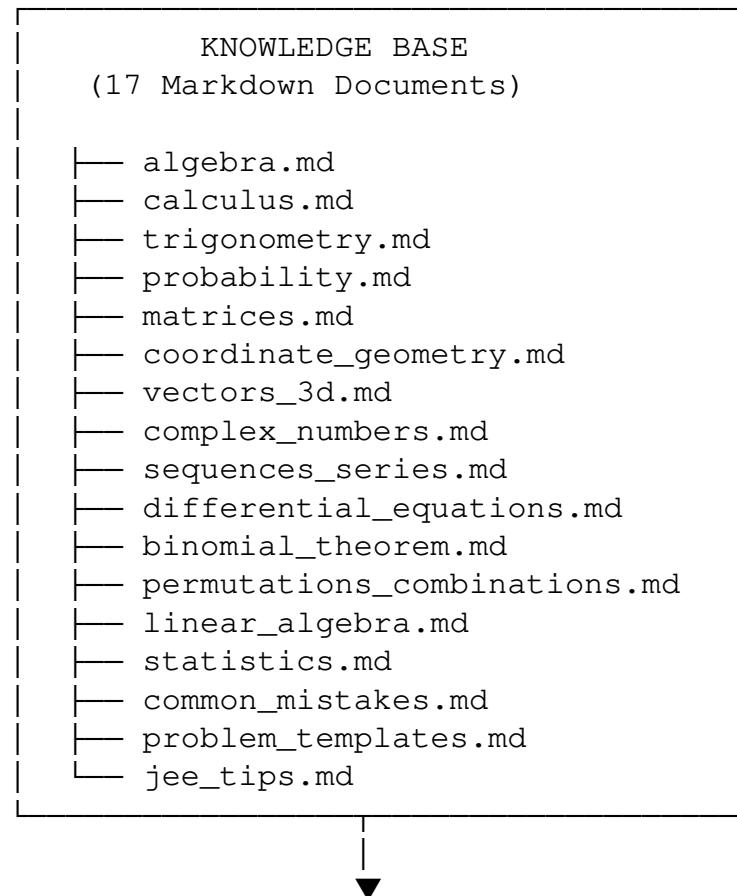
1. Convert technical solution to student-friendly format
2. Add step-by-step breakdown
3. Include key concepts
4. Add JEE exam tips

Output:

```
{
  "final_explanation": "Step 1: Factor x2 - 5x + 6...",
  "key_concepts": ["Quadratic Equations", "Zero Product Property"],
  "exam_tips": ["Always verify by substitution"]
}
```

3.2 RAG System Architecture

RAG SYSTEM COMPONENTS



INDEX BUILDING PIPELINE

- | 1. Load Documents | 2. Chunk Text | 3. Generate Embeddings |
|-------------------|---------------------------------------------------|-------------------------------------|
| Read .md files | Split into ~500 char chunks with 100 char overlap | all-MiniLM-L6-v2
384-dim vectors |
| Extract headers | | |
| Parse content | | |
|
 | | |
| 4. Build Index | 5. Store Metadata | |

FAISS IndexFlatIP
(Inner Product)

chunks.pkl
metadata.json

Result: 571 chunks indexed with semantic search capability

RETRIEVAL PIPELINE

Query: "How to solve quadratic equations"

1. Embed Query

all-MiniLM-L6-v2
384-dim vector

2. FAISS Search

k=5 nearest neighbors
Inner product score

3. Filter & Rank

Score threshold: 0.5
Return top matches

Output: Top-5 relevant knowledge chunks with sources

3.3 Memory and Self-Learning System

MEMORY & SELF-LEARNING SYSTEM

SQLite Database Schema

TABLE: problems

id (PRIMARY)	problem_text (TEXT)	solution (TEXT)	confidence (FLOAT)	feedback (TEXT)
uuid-1	"Solve x^2 "	" $x=2, 3$ "	0.93	"correct"
uuid-2	" $\int x^2 dx$ "	" $x^3/3+C$ "	0.87	"incorrect"

TABLE: feedback_log

problem_id (FK)	feedback_type (TEXT)	user_correction (TEXT)	timestamp (DATETIME)

SELF-LEARNING FLOW:

User Feedback

- ✓ Correct
- ✗ Incorrect

Memory Check

On new problem:
Search memory for

Solution Enhancement

If similar problem found:
- Use cached solution

If incorrect:
- Store correction
- Learn pattern

similar problems
by embedding
similarity

- Boost confidence
- Add source: "memory"

3.4 Input Processing Flow

INPUT PROCESSING DETAIL

TEXT INPUT:

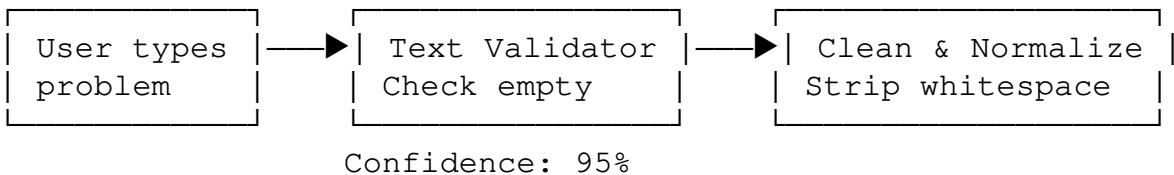
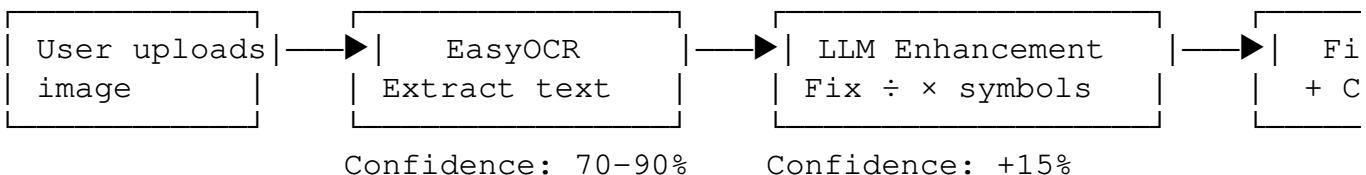
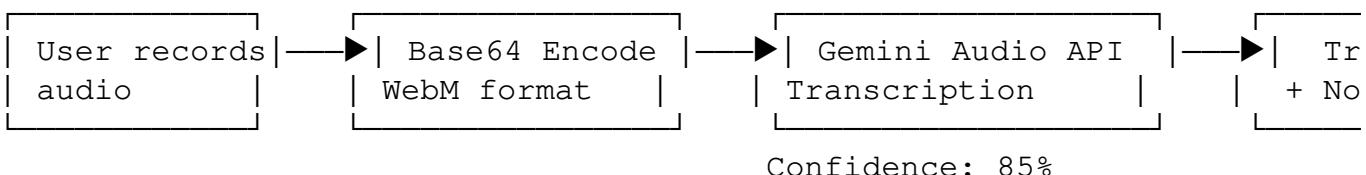


IMAGE INPUT (OCR) :



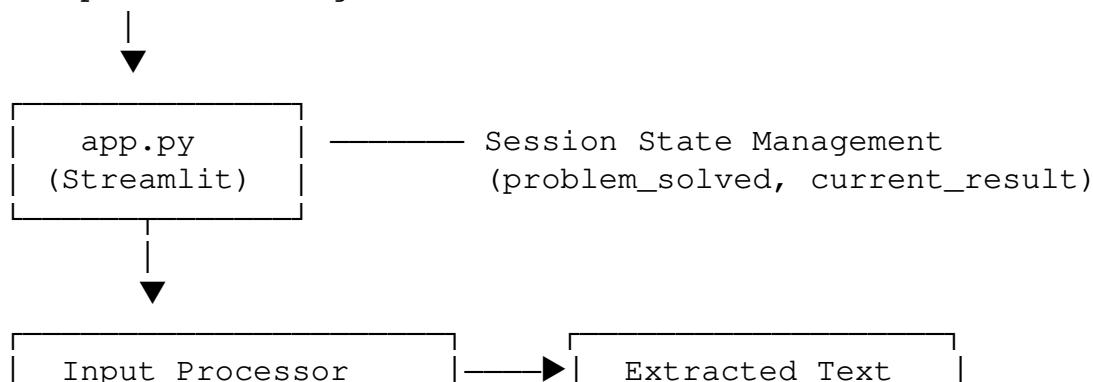
AUDIO INPUT (ASR) :

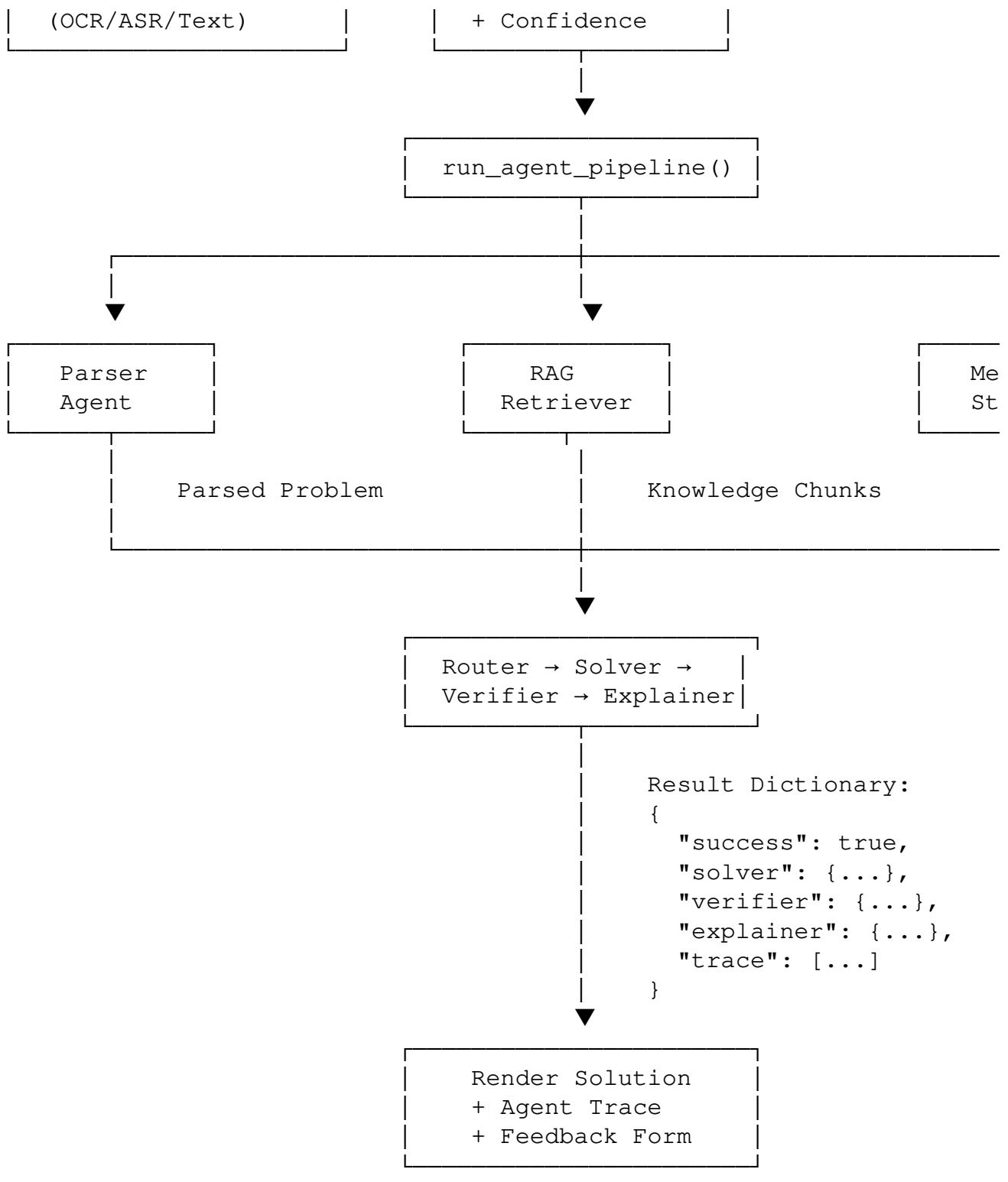


4. Data Flow Diagram

COMPLETE DATA FLOW

User Input (Text/Image/Audio)





5. Security & Error Handling

5.1 API Key Management

- Environment variables (.env)
- Streamlit secrets (for cloud)
- Never committed to git

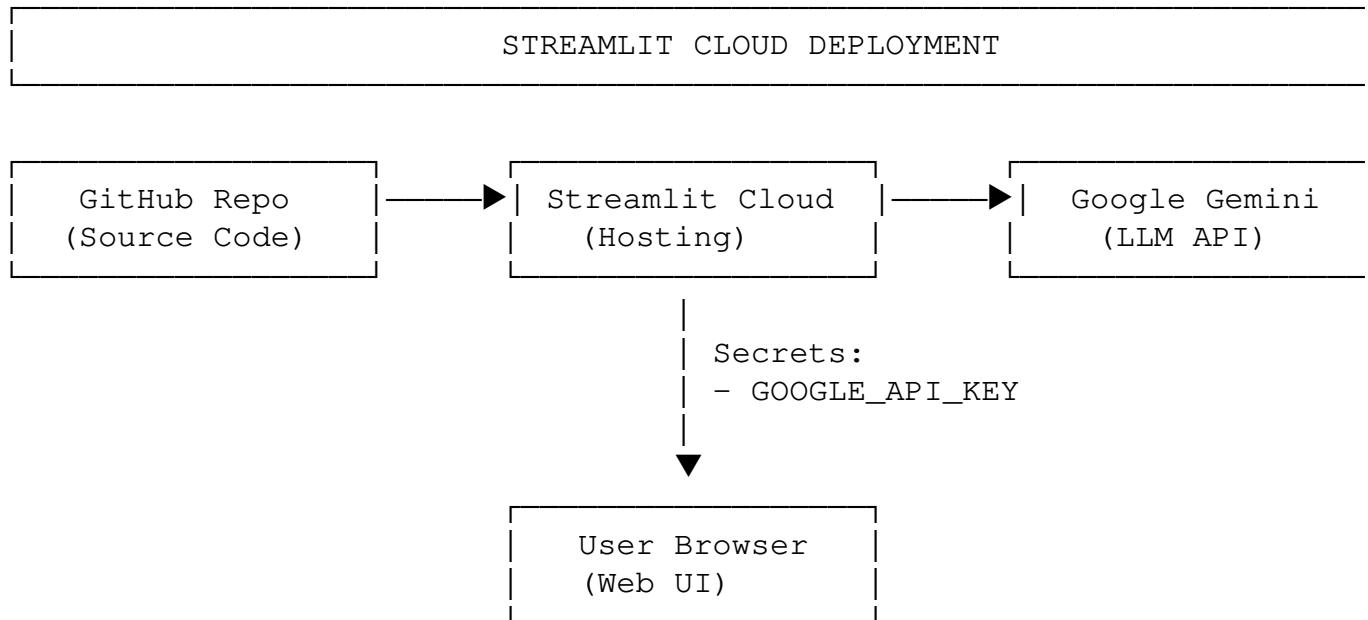
5.2 Error Handling Strategy

Component	Error Type	Handling
LLM Client	JSON Parse Error	Fallback to text parsing
LLM Client	Rate Limit	Retry with backoff
OCR	Low Confidence	LLM enhancement
ASR	Empty Transcript	User notification
Solver	Type Error	Type coercion
RAG	Index Not Found	Load on demand

5.3 HITL Triggers

Scenario	Threshold	Action
OCR Confidence Low	< 75%	Show edit box
Parser Ambiguous	N/A	Show clarification input
Verifier Uncertain	< 70%	Request human review

6. Deployment Architecture



Files Required:

```

├── app.py                      # Entry point
├── requirements.txt             # Dependencies
├── packages.txt                 # System packages
├── .streamlit/
│   └── config.toml              # Theme config
└── data/
    └── faiss_index/            # Pre-built index
  
```

7. Performance Metrics

Metric	Value
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