Final Architecture Report: The Automaton Auditor Swarm

Date: 2026-02-27
Status: Final Submission (Full Swarm: Detectives, Judges, & Supreme Court Operational)

1. Executive Summary

The **Automaton Auditor** has evolved from a forensic scanner into a production-grade **Autonomous Governance Swarm**. While the interim submission focused on robust evidence collection, the final implementation establishes a complete "Digital Courtroom" capable of nuanced interpretation and deterministic verdict synthesis.

The system now orchestrates a deep LangGraph topology featuring:

1. **Forensic Detective Layer:** AST-level code analysis and multimodal vision verification.
2. **Dialectical Judicial Layer:** Persona-driven adversarial deliberation.
3. **Supreme Court Layer:** Deterministic conflict resolution using hardcoded legal precedence.

The architecture successfully implements the **MinMax optimization loop**, moving beyond "Vibe Coding" into concrete architectural execution of **Metacognition** and **Dialectical Synthesis**.

2. Forensic Detective Layer: Deep Analysis Protocol

The Detective Layer is the foundation of the swarm, responsible for collecting objective evidence. We have moved beyond simple text search into structural verification.

2.1 structural AST Forensics (RepoInvestigator)

The RepoInvestigator uses a custom StateVisitor and SecurityVisitor to walk the Abstract Syntax Tree of the target repository.

- ➢ **StateVisitor Logic:**
  - ○ Recursively identifies ClassDef nodes named AgentState.
  - ○ Scans AnnAssign nodes for the Annotated type hint.
  - ○ Verifies the presence of operator.add or operator.ior reducers.
  - ○ **Verdict:** Prevents "State Overwrite" bugs by ensuring reducers are actually implemented, not just imported.
- ➢ **SecurityVisitor Logic:**
  - ○ Scans Call nodes for anti-patterns like os.system() or subprocess.run(shell=True).
  - ○ Rewards the use of tempfile and Path objects for sanitized I/O.

  - **Verdict:** Identifies "Security Negligence" that triggers a Chief Justice override.

2.2 Multimodal Architectural Verification (VisionInspector)

Fulfilling the "Swarm Visual" requirement, we implemented low-level image extraction from PDF reports.

- **Extraction Protocol:** Uses PyMuPDF (fitz) to extract binary image data from PDF page objects.
- **Multimodal Analysis:** These images are passed to **Gemini 2.0 Flash** with a specialized forensic prompt:

  > *"Analyze this architectural diagram. Does it show parallel fan-out for Detectives and Judges? Respond with keys: 'classification', 'is_parallel', 'description'."*

- **Metacognition:** The agent compares the visual diagram against its own AST-detected graph edges. If a developer claims a parallel swarm in their diagram but writes linear code, the VisionInspector flags an **Architectural Discrepancy**.

2.3 Forensic Path Cross-Referencing (DocAnalyst)

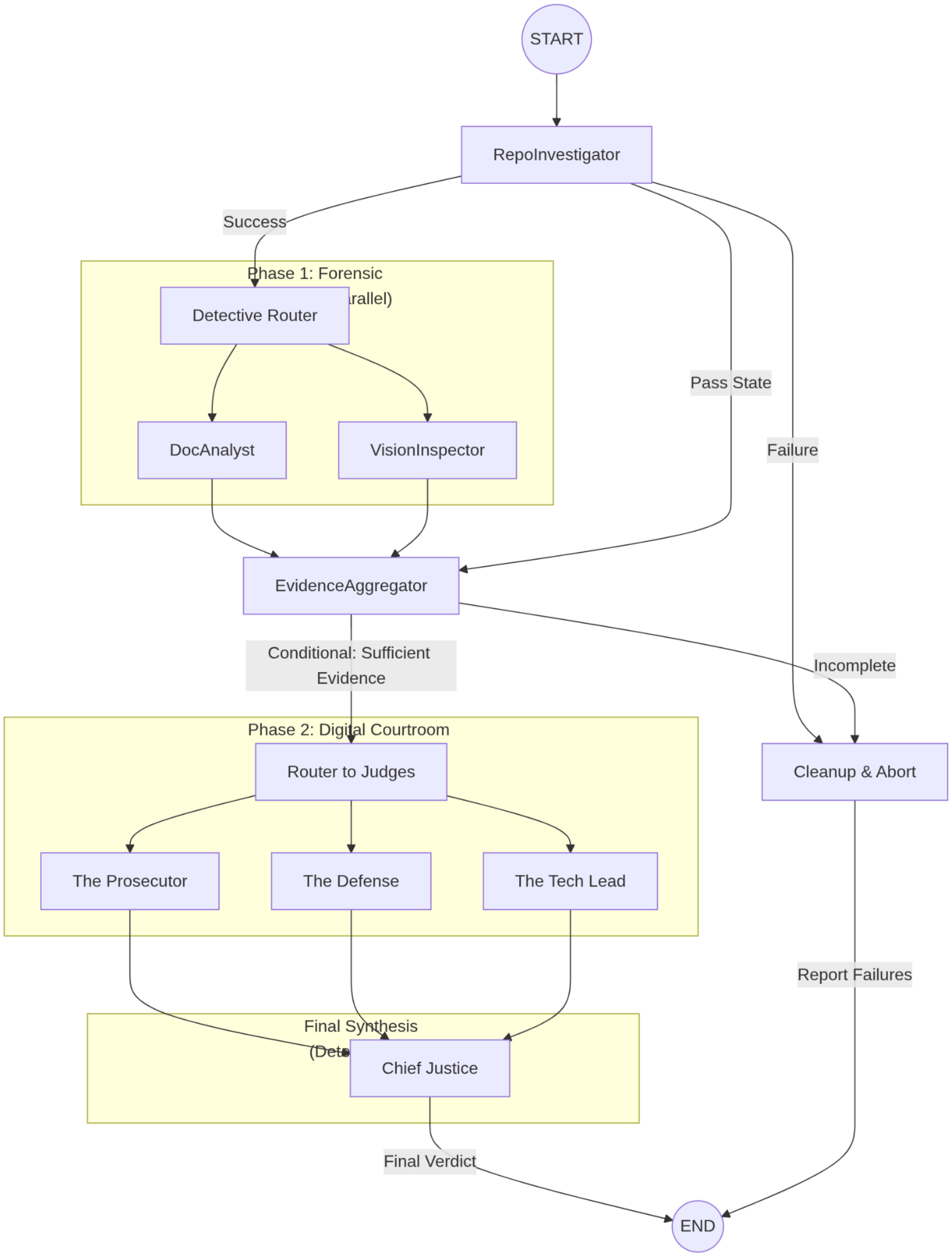
The DocAnalyst performs a forensic bridge between the documentation and the repository:

- **Procedure:** Extracts every file path mentioned from the PDF text using regex.
- **Verification:** Cross-references every claimed path against the actual files in the cloned sandbox.
- **Hallucination Detection:** If the report claims logic exists in non-existent folders, the system records a Hallucination Liability. (Verified against `src/graph.py`, `src/nodes/justice.py`, and `src/state.py`).

3. High-Fidelity Graph Orchestration

3.1 Digital Courtroom: Full Swarm Diagram

The current system implements a multi-phase parallel architecture, ensuring that objective forensic collection is isolated from subjective judicial interpretation.


START
RepoInvestigator
Success
Pass State
Failure
Phase 1: Forensic
rallel)
Detective Router
DocAnalyst
VisionInspector
EvidenceAggregator
Conditional: Sufficient Evidence
Incomplete
Phase 2: Digital Courtroom
Router to Judges
The Prosecutor
The Defense
The Tech Lead
Cleanup & Abort
Report Failures
Final Synthesis
(Dete
Chief Justice
Final Verdict
END

3.2 Fan-In / Fan-Out Mastery

The implementation features two distinct synchronization points:

➢ **Fan-Out**: The `detective_router` and `router_to_judges` nodes allow for maximum concurrency, scaling the audit horizontally.

➢ **Fan-In (State Synchronization)**:The `evidence_aggregator` and `chief_justice` nodes act as strict synchronization barriers. By utilizing LangGraph's functional reducers (e.g., `Annotated[List, operator.add]`), the system ensures that parallel updates to the global state are commutative and non-destructive. This "State Synchronization" prevents race conditions and ensures the judicial layer has the complete forensic corpus before deliberation begins.

4. The Digital Courtroom: Dialectical Judicial Nuance

We implemented a three-judge bench to ensure no single model's bias determines the grade.

4.1 Judicial Personas & Statutes

Each judge follows a strict "Constitution" defined in their prompt:

Judge	**Philosophy**	**Primary Statute**
The Prosecutor	Trust No One	**Statute of Orchestration:** Linear flows = Fail.
The Defense	Spirit of the Law	**Statute of Effort:** Reward AST complexity over syntax perfection.
The Tech Lead	Pragmatic Purity	**Statute of Engineering:** Typed schemas only; banish "Dict Soups."

4.2 Structured Output Enforcement

Every opinion is forced into a Pydantic JudicialOpinion model using .with_structured_output(). This ensures:

1. **Point Rigidity:** Scores are forced into a k of ${0, 7, 12, 15, 21, 25, 30, 35}$ for 35-point dimensions.
2. **Cited Evidence:** Judges *must* cite specific detective evidence by ID, preventing generic LLM "vibes."

5. The Supreme Court: Deterministic Synthesis Logic

The ChiefJusticeNode is the only node that doesn't use an LLM. It is a pure logic engine that applies deterministic resolution rules:

```
# Rule of Security (Protocol B.2)

if prosecutor.cites("Security Negligence"):

    final_score = min(avg_score, 7) # Hard cap at Level 1/2

    remediation = "CRITICAL SECURITY OVERRIDE TRIGGERED"

# Rule of Evidence (Protocol B.3)

if doc_analyst.hallucination_detected:

    final_score = min(final_score, tech_lead.score) # Strip Defense bonus
```

5.1 Synthesis Resolution Rules

1. **Security Override:** If any severe security flaw is found, the dimension score is capped regardless of other judges' optimism.
2. **Fact Supremacy:** If a detective's objective finding (e.g., found=False) contradicts a Judge's claim, the objective finding wins.
3. **Functionality Weight:** The Tech Lead's score carries 50% weight for technical dimensions (Graph Orchestration, Safe Tooling).
4. **Dissent Summary:** If the score variance between judges exceeds 10 points, the Chief Justice generates a manual review flag.

6. Implementation Roadmap & Feedback Progress

6.1 MinMax Optimization History

- **Stage 1 (Interim):** Implemented basic Detective Layer. Relied on regex.
- **Stage 2 (Refinement):** Upgraded to AST visitors. Added parallel Judges but lacked synchronization.
- **Stage 3 (Final):** Fully synchronized fan-in/fan-out. Implemented hardcoded Synthesis rules. Fixed "No Exchange" scoring logic.

6.2 Future Improvements

- **Tree-Sitter Integration:** To support auditing across multiple languages (JS/TS, Rust).
- **History Summarization:** For huge repositories, implement a Summarization node before the Judges to stay within context windows.

7. Technical Deliverables & Footprint

- **src/state.py**: Pydantic models with Annotated reducers for parallel state management.
- **src/tools/safety.py**: Centralized sandboxing and shell-less execution.
- **src/nodes/justice.py**: The deterministic "Supreme Court" logic.
- **audit/reports_generated/**: Final Markdown verdicts with Dissent Summaries and Remediation Plans.