Converting Natural Language From Complex Procedural Documents To Structured Diagrams

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Table of Contents

Table of Contents

Motivation

- As procedural documents grow in volume, interpreting them remains time-consuming and expert-dependent.
- Flowcharts help reduce cognitive load and improve understanding.
- Advances in LLMs and retrieval enable smarter document visualization.
- Yet, there's no standard metric to evaluate text-to-flowchart transformation.

Objectives

- Develop a method to transform procedural documents into interactive flowcharts with support for clarification queries.
- Implement an evaluation framework and experiment to measure the effectiveness of AI in converting documents into flowcharts.
- Deliver a system that is user-friendly and supports expert-guided refinement through a human-in-the-loop approach.

Natural Language Understanding

LLMs apply transformer-based attention to understand context, semantics, and procedural flow, allowing them to identify steps, conditions, and relationships in unstructured text.

Actors & Features

Actors:

- **User:** a technical staff, analyst, or domain expert who uploads documents, explores flowcharts, validates results, and may refine the output manually.
  In some cases, the user also plays the role of an expert verifier.
- **AI Engine (IUFlowGen):** automated system that uses LLMs and retrieval techniques to generate draft flowcharts and respond to clarification queries.

Features:

- **Send Document** — performed by User
- **Plot and Query** — performed by AI Engine
- **Interact and Ask** — performed by User

Contributions

Scientific Contribution

Formalize a modular AI pipeline that combines retrieval, prompting, and DOT visualization, and propose a metric to evaluate the effectiveness of transforming complex documents into structured flowcharts.

Real-world Contribution

Aid users in understanding procedural documents through interactive visual flowcharts, applicable in education, healthcare, technical documentation, and many more.

Table of Contents

Advancements

- GenFlowchart applies generative AI to understand and segment flowchart diagrams.
- Lester et al. introduce multi-phase summarization for long regulatory documents.
- ChatGPT identifies procedural steps and actors using advanced NLU capabilities.
- Eraser Flowchart Maker supports text-to-diagram generation with intuitive UI.

Research Gaps

Research gap 1

Current AI systems lack interactive flowchart generation that preserves procedural logic and structure from unstructured documents.

Research gap 2

The combination of AI-guided generation with graph and vector representations for storing and retrieving steps, entities, and relationships is still under-discovered in procedural document understanding.

⇒ **A new approach that builds graph-augmented prompts and renders interpretable flowcharts locally can fill this gap.**

Technical difficulties

- The amount of background knowledge required to combine graph theory, vector search, and prompt engineering is substantial.
- LLMs are probabilistic, which introduces unpredictability in output consistency, especially for structured generation tasks.
- Mapping AI-generated content into structured and verifiable DOT code demands careful post-processing and validation.

Table of Contents

System overview

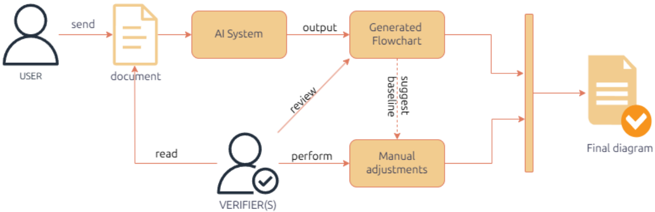
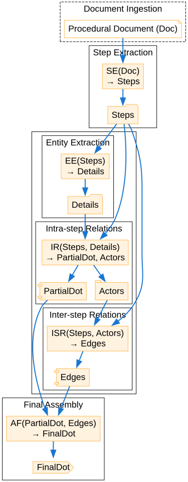


Figure: System overview of UIFLowGen Protocol

Process - Flowchart Generation

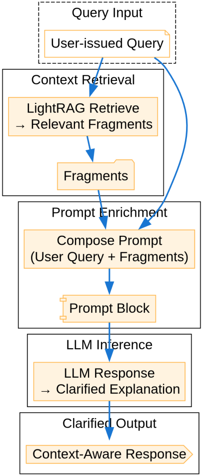
Algorithm Pseudocode



- **Goal:** convert procedural documents into structured flowcharts via automated step/entity extraction and reasoning.
- **Result:** generate a valid FinalDot representation used for rendering interactive flowcharts.
- **Step:** extract steps → enrich with entities → infer relations → assemble graph.
- **Scope:** execute locally with LLMs, LightRAG, regex post-processing, ensuring offline reproducibility.

Process - Query

Algorithm Pseudocode



- **Goal:** support users and verifiers in exploring or confirming specific flowchart elements or logic.
- **Result:** generate a context-aware explanation or inference tied to queried nodes or actions.
- **Step:** receive query → retrieve relevant content → compose enriched prompt → return response.
- **Scope:** acts as an interactive support layer during review.

Table of Contents

Prototyping

GitHub repository: `https://github.com/Khim3/IUFlowGen`

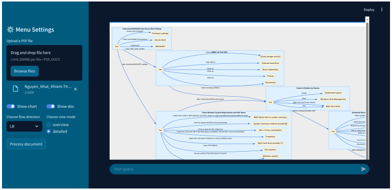


Figure: Generated flowchart from document.

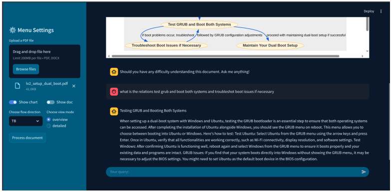


Figure: Clarification query interface

Experiment Setup

- An experiment was conducted with **10 participants**, divided into two groups:
  - **Group 1**: Without AI assistance
  - **Group 2**: With IUFlowGen (AI-assisted)
- Participants completed flowchart tasks from procedural documents across **four levels of increasing complexity**.
- All tasks were conducted under **time constraints** and **supervised by Dr. Tran Thanh Tung**.
- For the final two tasks, results were evaluated using five expert rubrics:
  Rubrics: Step Coverage, Logical Flow, Relation Accuracy, Entity Representation, Structural Clarity

Benchmark Results

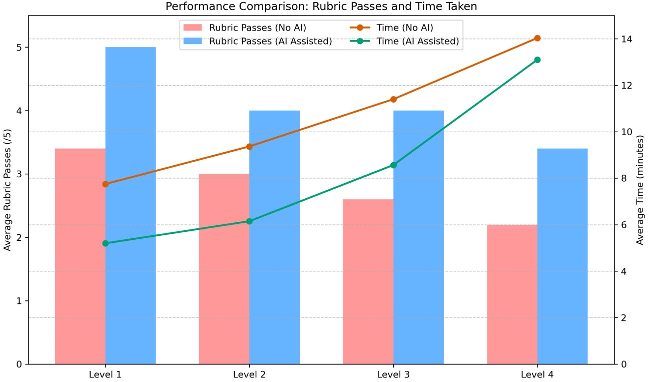


Figure: Comparison of average rubric and time across document complexity levels.

Table of Contents

Analysis

- The system provides high interpretability and transparency by visualizing extracted procedural logic in a human-readable form.
- The interactive human-in-the-loop model empowers domain experts to validate and refine AI-generated flowcharts.
- IUFlowGen adapts well to varying document complexity, demonstrating strong flexibility across synthetic and real-world texts.
- Designed to operate on local infrastructure, the system performs reliably in resource-constrained or offline environments.

Limitations

- Entity extraction and semantic embedding are resource-intensive, causing latency on low-power machines.
- LLM-based generation is non-deterministic, leading to occasional inconsistencies that require human correction.
- The system supports only single-user, sequential document processing, limiting scalability in multi-user scenarios.
- Performance depends on the clarity and structure of the input document, especially for domain-specific texts.

$\Rightarrow$ **Despite these limitations, IUFlowGen establishes a reliable base for AI-assisted procedural comprehension.**

Table of Contents

Summary

- **Built for many applications:** IUFlowGen enables automated, interactive flowchart generation from procedural text, suitable for use in education, healthcare, compliance, and technical documentation, etc.
- **Ready for practical adoption:** Designed for offline deployment, IUFlowGen is accessible to end users, organizations, and domain experts needing secure document visualization tools.

Future Works

- Improve UI/UX design with real-time feedback, interactive previews, and adjustable layout controls for better user experience.
- Enable direct flowchart editing, including drag-and-drop, node repositioning, and in-place corrections.
- Package the system for web or mobile deployment to improve accessibility in education, legal, and enterprise settings.

Demonstration

Process A

Visualize the flowchart from an uploaded procedural document.

Scenario 1

Successful generation and rendering of a valid procedural flowchart.

Scenario 2

Clarification query triggered on a node to retrieve related explanation.

Process B

Perform a query from the generated chart to aid user understanding.


thank
you!