Project Description

This research pioneers a novel AI system that performs mathematical reasoning to generate graph drawings based on specified properties. By leveraging generative AI capabilities and multi-modal learning approaches, our model will create visual representations of graphs that satisfy complex mathematical constraints like planarity, Hamiltonicity, and bipartiteness.

For example, given a natural language input like ”generate a Hamiltonian graph with 20 nodes,” the model will reason about the requirements and generate a visual drawing of a graph that contains exactly 20 nodes and guarantees the existence of a cycle visiting each node exactly once.

Key innovations:

- First AI model that performs mathematical reasoning to draw graphs satisfying complex properties
- Advances in generative AI by creating a system that produces mathematically valid graph visualizations
- Multi-modal approach combining textual property descriptions with visual graph generation
- Novel architecture for reasoning about and satisfying mathematical constraints

Technical Significance

This project introduces fundamental advances in AI capabilities:

- **Mathematical Reasoning:** Our model will be the first to actively reason about graph properties and construct valid visual representations
- **Property-Driven Generation:** The system generates visual drawings that demonstrate understanding of mathematical constraints
- **Complex Property Handling:** Model reasons about and satisfies combinations of properties (e.g., ”generate a planar, bipartite graph with 15 nodes and maximum degree 3”)

Measurable Goals and Objectives

- **Dataset Creation:** Create training dataset of at least 2,000 graph-property pairs where graphs are images and the properties are in natural language text
- **Model Performance:**
  - Adopt evaluation metrics such as F1-score to measure reasoning capability for single properties
  - Assess the model’s ability to handle property combinations
  - Measure computational efficiency and generation quality

Project Timeframe (Summer 2025)

- Month 1 (June 2025)
  - Weeks 1-2: Dataset creation and annotation
  - Weeks 3-4: Model architecture development and initial training
- Month 2 (July 2025)
  - Weeks 1-2: Model refinement and performance optimization
  - Weeks 3-4: Evaluation, documentation, and paper writing

Enhancement of Teaching/Research at Lincoln University

- Research Impact
  - Position Lincoln University as a pioneer in AI-driven mathematical visualization
  - Create opportunities for follow-up research projects
  - Generate preliminary results for larger external grants
- Teaching Integration
  - Demonstrate AI capabilities in advanced CS courses

Outcome Measurement Methods

- Technical Evaluation
  - Mathematical validation of generated graphs
  - Performance metrics on property satisfaction
  - Processing time and resource requirements
- Research Impact Metrics
  - Publication in AI conference

Plans for Sharing Results

- Present results at Faculty Development Conference as required by FRDC guidelines
- Submit research findings to AI conferences
- Resource Sharing
  - Release dataset and code on GitHub
  - Publish technical documentation