

Energetic Pathfinding and Perceptual Heuristics in Manhattan Navigation

CIS 667: Introduction to Artificial Intelligence

Gil Raitses

Invalid Date

Introduction

Subject Area

Artificial Intelligence – Search and Reasoning Systems.

The project focuses on heuristic search, knowledge representation, and perception-based reasoning, linking foundational AI theory to real-world sensory modeling.

Problem Statement

Traditional pathfinding algorithms optimize for geometric distance or time but fail to capture the energetic and perceptual dynamics of real-world movement. In dense environments like Manhattan, cost is not defined by distance alone but by sensory and behavioral complexity—crowding, visual noise, and movement unpredictability.

The problem addressed here is how to design an intelligent agent capable of integrating sensory context into its reasoning process for route selection. The project reimagines the A* search paradigm with a perceptually informed heuristic derived from camera data, modeling what it means for an agent to “feel” resistance in the environment it navigates.

Aim of the Project

To implement and evaluate a heuristic search system that learns energetic pathfinding behavior by integrating sensory data into classical A* reasoning, demonstrating how perception-driven cost modeling can improve interpretability and environmental realism in AI navigation.

Objectives

1. Define a Manhattan-based navigation environment between Grand Central Station and Carnegie Hall using a grid of intersections as states.
2. Construct a knowledge base from NYC traffic-camera data, translating visual detections into symbolic features representing environmental conditions (bikes, cars, pedestrians, obstructions).
3. Develop a perceptually weighted heuristic that adapts energetic cost functions based on visual context.
4. Implement A* search and compare it to standard Manhattan-distance-only heuristics.
5. Evaluate differences in efficiency, realism, and interpretability between baseline and perceptual systems.
6. Present visualizations showing how sensory context alters route choice and total cost.
7. Reflect on implications for embodied AI and human-centered navigation modeling.

Team Information

Gil Raitses

- **Role:** Individual project lead
- **Email:** [YOUR_SU_EMAIL]
- **Phone:** [OPTIONAL_PHONE]
- **Affiliation:** Syracuse University, Data Science / HCII Program

Project Type and Rationale

This is an **Applied Project** (category (d) from the guide).

This project applies heuristic search and reasoning methods learned in class to a realistic urban navigation task. It connects theoretical AI models to sensory data from a dynamic real-world environment, extending the notion of cost and optimality to include perceptual load and behavioral friction. It exemplifies how AI systems can transition from abstract reasoning to embodied decision-making.

Work Plan

Initial Work Plan

- **Week 1–2:** Review relevant algorithms from course material (uninformed search, informed search, constraint satisfaction).
- **Week 3:** Preprocess NYC traffic-camera dataset and extract feature sets (density, obstructions, flow).
- **Week 4–5:** Build knowledge base and assign weighted costs to edge transitions.
- **Week 6:** Implement classical A* with Manhattan heuristic.
- **Week 7–8:** Develop perceptual heuristic integrating vision-derived features.
- **Week 9:** Compare performance metrics and generate visualizations.
- **Week 10:** Draft final report and presentation materials.

Individual Work Plan

Gil Raitses Responsibilities:

- Collect and preprocess visual dataset.
- Design heuristic and cost models.
- Implement algorithm and testing pipeline in Python.
- Analyze results and document findings.
- Prepare submission materials and presentation.

Shared Tasks: N/A (individual project).

Methodology Summary

The agent's reasoning follows the PEAS framework (Performance, Environment, Actuators, Sensors). The environment is a discretized Manhattan grid; performance is measured by minimal energetic cost; sensors derive context from traffic-camera imagery; actuators represent directional movements.

The heuristic integrates classical pathfinding logic with environmental features to approximate human-like reasoning about effort. Constraint satisfaction logic filters infeasible or undesirable paths. The

resulting system demonstrates how AI agents can merge perception with symbolic reasoning in practical navigation scenarios.

Expected Contributions

The project demonstrates how informed search can evolve toward perceptually grounded reasoning. It contributes an applied framework that makes heuristic logic interpretable, showing the connection between environmental perception and decision-making. It also bridges course concepts—state-space search, heuristic admissibility, knowledge representation, and CSP integration—through a single coherent implementation.

References

- Russell, S., & Norvig, P. (2022). *Artificial Intelligence: A Modern Approach* (4th ed.). Pearson.
- Thrun, S., Burgard, W., & Fox, D. (2005). *Probabilistic Robotics*. MIT Press.
- NYCDOT Open Data Portal. (2024). *NYC Traffic Camera Dataset*.
- Bengio, Y., et al. (2016). “Learning Deep Architectures for Structured Prediction.” *Foundations and Trends in Machine Learning*.
- Sun, J., Parks, S., & Raitses, G. (2024). *Annotation Systems for Behavioral Classification*. Parks Lab Research Notes, Syracuse University.
- Litwin-Kumar, A., & Abbott, L. F. (2021). “Learning and Adaptation in Neural Circuits.” *Annual Review of Neuroscience*.