Modeling Diagrammatic Reasoning – Route Planning on a Grid Based Map

Dr. H. A. Dye, Davies Fellow, USMA

Dr. Laurel Allender, ARL

Introduction

- Maps are diagrammatic abstractions of geospatial information
- Problem solving involving diagrams:
  - Route planning
  - Situational awareness updates

Utilize Diagrams to:

- Present information so that it can be rapidly assimilated
- Organize all essential information
- Prevent information loss
- Assist the reasoning process – develop automated systems that present possible courses of action

Challenges to Developing Automated Diagrammatic Reasoning

- Currently perception of diagrams and cognitive problem solving are modeled separately
- Understanding relationship between perception and problem solving
- Avoid brute force productions in the cognitive model

Three Year Davies Fellow Effort

- Leverage two disciplines:
  - Mathematics
  - Computational Cognitive Modeling
- Goal: Enable reasoning from diagrams in a cognitive modeling architecture

Methodology

- Model diagrammatic reasoning in the ACT-R cognitive architecture
- Understand limitations and advantages of diagrammatic reasoning
- Understand timing – how long tasks take
- Understand the state of the art in modeling the link between perception and symbolic reasoning
- Understand how visual attention is distributed

Diagrams

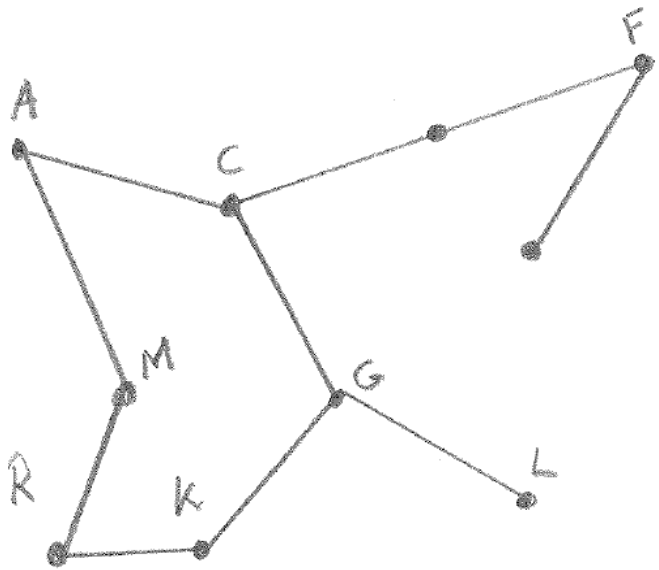
- Eliminate inessential information
- Contain abstracted data
- Provide an organizing schema for the information
- Consist of primitive objects: lines, points, and regions

From Bannerjee and Chandrasekaran et. Al 1999, unpublished manuscript

Diagrammatic Information

- Determined by relationships between objects
- Codifies relationships that can be immediately perceived
- Emergent objects and more complex relationships are determined by multiple relationships

Information Extraction



Information obtained:

- The path (edge) between location A to location C is one unit long
- The path (edge) between location C and location F is two units long
- This indicates that a path of length 3 exists between location A and location F

Reasoning Process

- Observe objects and relationships
- Create, modify, and delete objects
- Use knowledge to choose actions (described by productions) to achieve goals, specifically planning a route

Properties of Diagrams

- Intrinsic Properties – determined by the geometric and topological properties of the flat plane
- Extrinsic Properties – determined by the objects in the diagrams
- Diagrams establish limitations and an organizing schema that are not available in text-based representations

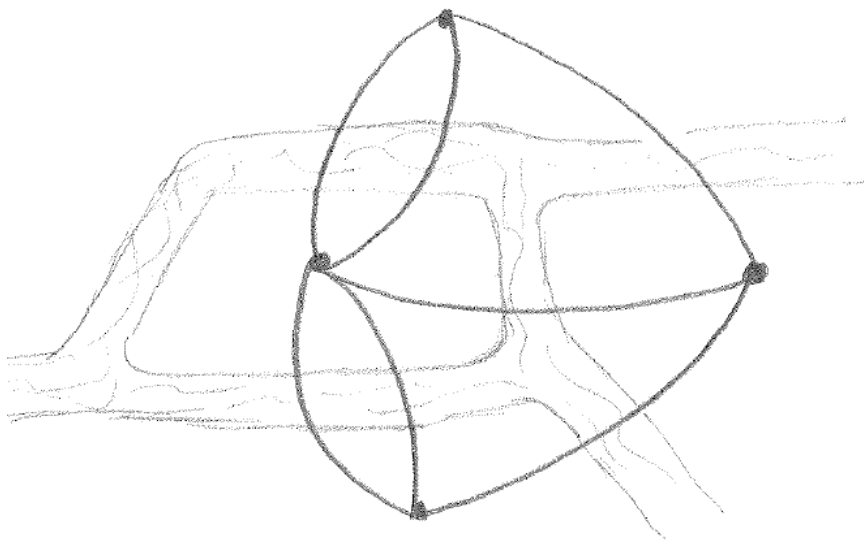
Implementing a Cognitive Model

- Visual perception – shift visual attention, focus on an area, and encode the information
- Develop a course of action based on encoded and processed visual percepts
- Plan a shortest route based on the visual information and its match to the route planning goal

The Koenigsburg Bridge Problem

- Is there a path that traverses each of the 7 bridges in Koenigsburg exactly once?
- Euler transformed the information into a graph
- The graph eliminates all inessential information

Euler’s Graph



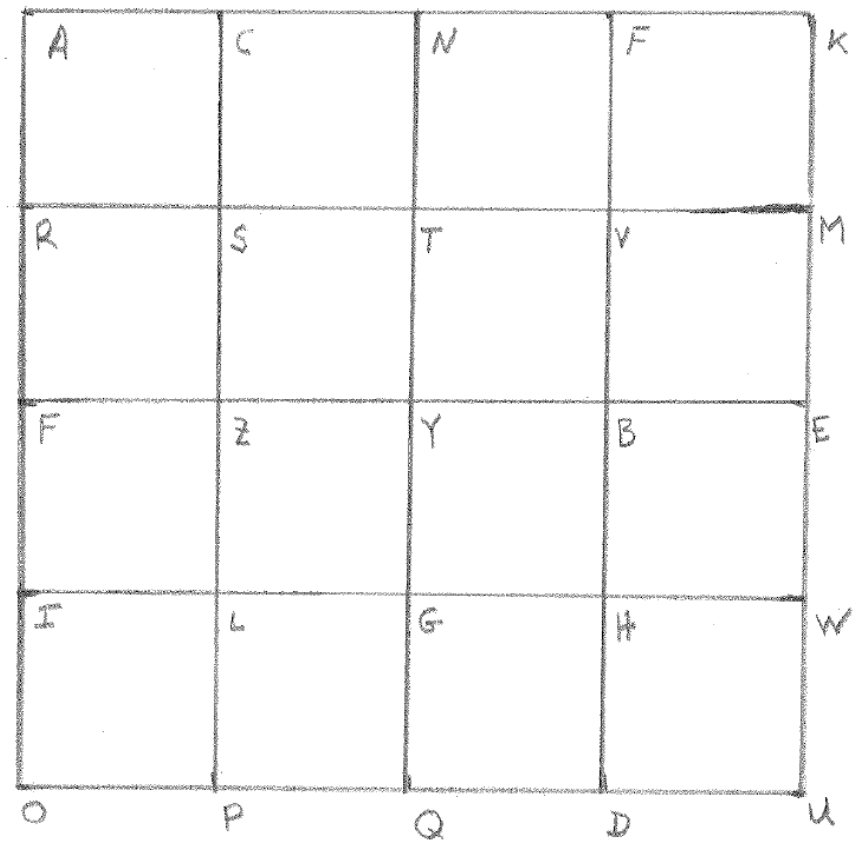
The Solution

- Euler determined that street information was irrelevant to the problem
- The key information: bridge accessibility
- The abstracted diagram allowed Euler to realize that no such path existed

The Cognitive Model

- Given a grid-based map, find a shortest route from location A to location B.

The Map



The Model Cont’

- The model scans the map to find location B
- The model plans a route from location A to location B
- Information is collected about the length of time require to find B and plan the route
- Information about the route is collected

Assumptions

- A user will follow a scan path to visually process the diagram.
- The regularity of the grid will cause a user to realize:
  - The locations occur at regular intervals.
  - Any two locations are connected by a path.
- The map will be used as short term memory.

Cognitive Activities of the Model

- Visual perception
- Perception routines:
  - What to do when the edge of the grid is reached
  - What to do when location B is found
- Problem solving:
  - How to find a shortest route once the position of location B is found

Future Plans – The Experiment

- Verify the cognitive model of route planning
  - Small scale
  - Verify timing of cognitive activities
  - Verify scan path
  - Compare shortest paths produced by humans and the model

Future Plans – Subway Model

- Model route planning on a subway
  - Subway routes form graphs
  - Can only traverse edges, not regions
  - Available information in a subway is sharply limited, creating a more realistic model

Linkages to Other ARL Research

- Advanced Decision Architectures Collaborative Technology Alliance
  - The Ohio State University Laboratory for Artificial Intelligence ~ Dr. Chandrasekaran
  - Carnegie Mellon University Social & Decision Sciences ~ Dr. Gonzalez
  - Micro Analysis & Design ~ Dr. Lebiere & Dr. Best
- ARL-HRED Cognitive Sciences Branch
  - Computational Cognitive Modeling

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