RMP Milestone Journal A

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Abstract— This journal explores the initial steps in designing an AI agent to solve problems inspired by Raven's Progressive Matrices (RPM). The approach begins with a human perspective, identifying geometric patterns, recognizing transformations, and counting elements as key strategies for solving RPM problems. Three example problems illustrate these principles in action. The agent design incorporates semantic networks to represent relationships between shapes and uses a generate-and-test method to hypothesize and evaluate potential solutions. Several challenges are anticipated in the development process, including the complexity of pattern recognition and the need for the agent to adapt and generalize across different problem types.

1 HUMAN APPROACH

As a human, the goal of the Raven's Progressive Matrices (RPM) test is to apply abstract reasoning and identify patterns or relationships between figures in a 2x2 or 3x3 matrix to determine the correct answer. To identify the patterns, and ultimately solve the problem, we look to identify geometric patterns, recognize a transformation, and/or count elements. This combination of problem observations allows us to systematically analyze the figures, understand the underlying rules governing their arrangement, and accurately determine the missing element by ensuring consistency with the established patterns

1.1 Example of 2x2 RPM Problem: Basic Problem B-01

The problem shown below in figure 1 is the first problem in the basic problem category. In solving Basic Problem B-01 from a human perspective, the approach of identifying geometric patterns, recognizing transformations, and counting elements can be applied to find the solution. The first step involves observing that the problem consistently uses simple geometric shapes across the grid. That is, black squares inside white squares. Recognizing this geometric pattern sets the expectation that the missing figure should also follow this structure. Upon further examining of the figures (A, B, and C), it becomes clear that all the squares are of the same size and centered within the white square, indicating that there is no transformation of size or position. This consistency in the arrangement reinforces the expectation that the missing figure should maintain the same centered black square pattern. Finally, counting elements confirms that each figure contains a single black square within the white square, maintaining uniformity. By combining these observations the correct answer is determined to be the figure that continues this consistent pattern, which is **Answer 2**.

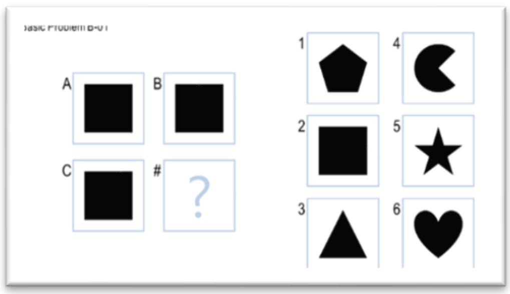

Figure 1—Ravens Progressive Matrices 2x2 problem. Basic Problem B-01.

1.2 Example of 3x3 RPM Problem: Basic Problem D-03

To solve Basic Problem D-03 pictured in figure 2 below, the human approach again involves identifying geometric patterns, recognizing transformations, and counting elements. The first row (A, B, C) shows a pattern where a new shape is added with each step: starting with a circle, then adding a triangle and a circle, and finally including a square along with the other shapes. The second row (D, E, F) rearranges and changes the order of the shapes while maintaining the same set of elements. The final row (G, H) follows a similar progression of rearranging shapes. By counting elements and observing the transformations in both horizontal and vertical rows, it becomes clear that the pattern involves simplification in the final position, leading to a single circle as the correct shape. As such, **Answer 3**, which contains only a circle, correctly follows the established pattern and is the correct answer.

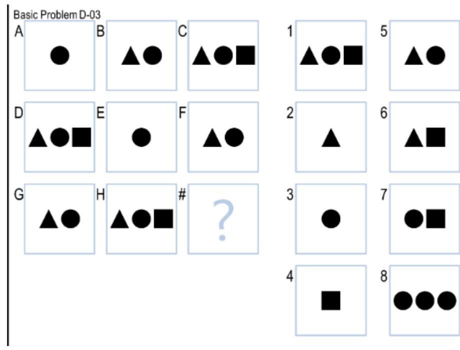

Figure 2 — Ravens Progressive Matrices 3x3. Basic Problem D-03.

1.3 Example of 3x3 RPM Problem: Challenge Problem C-09

In solving Challenge Problem C-09 pictured below using the principles described in the previous two problems again proves to be a very human approach to finding the correct answer. By analyzing the progression of shapes within each row, noting the consistent relationships between larger and smaller shapes, and observing how these relationships evolve through transformations like rotation or scaling, it becomes possible to predict the next figure in the sequence. In figure 3 below, the first row displays a transformation of polygons with smaller shapes inside, the second row follows a similar pattern with circles, and the third row shows diamonds that nest smaller diamonds within them. As a result, the correct answer, **Answer 7**, aligns with the established pattern and transformation, making it the logical continuation of the sequence.

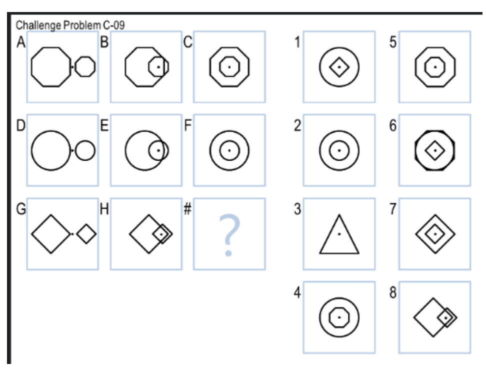

Figure 3 — Raven Progression Matrices 3x3. Challenge Problem C-09.

2 AGENT APPROACH

In designing an agent to solve Raven's Progressive Matrices-inspired problems, semantic networks and a generate-and-test method could play crucial roles in effectively identifying and applying patterns to solve the RPM problems.

2.1 Semantic Network

A semantic network is a knowledge structure that depicts how concepts are related to one another and how they interconnect [1]. In the context of solving these problems, a semantic network could be used to represent the relationships between various geometric shapes and their attributes, such as size, position, color, and relative orientation. For example, in Challenge Problem C-09 where a circle is inside a larger circle, the semantic network would represent this relationship as a link between the "circle" nodes with an "inside" relationship connecting them. By doing this, the agent could use the semantic network to understand the structural and relational patterns within the problem set. Moreover, by mapping each figure in the matrix to a semantic network, the agent can compare these networks across different cells to identify consistent relationships or transformations, such as a shape being consistently rotated, or a smaller shape being added inside a larger one.

2.2 Generate-and-Test Method

The generate-and-test method is an approach where the agent generates potential solutions and then tests them against specific criteria to determine the best fit. More specifically, it is a heuristic search technique based on Depth First Search with Backtracking which guarantees to find a solution if done systematically and there exists a solution [2]. By using this technique, all the solutions are generated and tested for the best solution. Applying the generate-and-test method to solving the RPM problems, the agent could generate multiple possible solutions based on the patterns identified on the semantic network outlined above. For example, if the semantic network reveals a pattern of increasing complexity (e.g., adding an additional shape in each step), the agent could generate candidate figures that adhere to this pattern.

Vital to the generate-and-test method, once the potential solutions are generated, the agent would then test each one against the constraints and rules derived from the semantic network. The testing phase would involve comparing the generated figures to the figures in the matrix to ensure consistency with observed transformations, such as maintaining the same number of shapes, following a specific rotational pattern, or preserving the relative positions of elements.

3 DESIGN CHALLENGES

Several challenges come to mind when thinking about the design of an agent to solve the RPM problems using the approaches outlined in the first and second bullet points.

3.1 Complexity of Pattern Recognition

One of the primary challenges will be enabling the agent to accurately recognize and interpret complex patterns, particularly when those patterns involve subtle transformations or nuanced relationships between shapes. Because the Raven's problems often require identifying not just simple sequences, but also compound patterns involving multiple variables, the agent will have to rely on explicit rules or algorithms to detect patterns. Ensuring that the algorithms are robust enough to handle the wide variety of patterns present in the problem sets, without overfitting to specific types of patterns, will be difficult.

3.2 Adaptability and Generalization

Ensuring that the agent can adapt to different types of problems and generalize its strategies across various problem sets is another key challenge. The agent needs to be flexible enough to switch between different problem-solving strategies based on the specific characteristics of the problem it encounters. Hence, an agent that is too rigid in its pattern recognition or hypothesis generation may perform well on one type of problem but fail on another. The challenge with adaptability and generalization will be in implementing the agent such that it can dynamically adapt its approach while maintaining consistency in performance across diverse problems.

Citations

[1] Gillis, A. S. (2024, January 18). *semantic network (knowledge graph)*. Content Management. https://www.techtarget.com/searchcontentmanagement/definition/semantic-network-knowledge-graph#:~:text=A%20semantic%20network%20is%20a,and%20call%20attention%20to%20relationships.

[2] GeeksforGeeks. (2021, January 22). *Generate and test search*. GeeksforGeeks. https://www.geeksforgeeks.org/generate-and-test-search/