Artificial Intelligence

Assignment 02

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Shelf Optimization Using Genetic Algorithm

1. Introduction This project focuses on optimizing the placement of products across various shelf types while adhering to constraints such as weight limits, refrigeration requirements, and hazardous material placement. A Genetic Algorithm (GA) was utilized to identify an efficient shelf arrangement that minimizes constraint violations and maximizes space utilization.

2. Methodology The optimization process follows a Genetic Algorithm approach, comprising the following steps:

Step 1: Problem Definition A set of shelves is given with specific weight capacities:

- **S1 (Checkout Display)** - 8kg
- **S2 (Lower Shelf)** - 25kg
- **S3 (Eye-Level Shelf)** - 15kg
- **S4 (General Aisle Shelf)** - 20kg
- **R1 (Refrigeration Zone)** - 20kg
- **H1 (Hazardous Zone)** - 10kg

A collection of products is provided, each having a name, weight, and specific storage constraints.

Step 2: Initial Population Products are randomly assigned to shelves while ensuring fundamental constraints (e.g., perishable goods in R1 and hazardous materials in H1).

Step 3: Fitness Evaluation The fitness function penalizes the following:

- Overloaded shelves (exceeding weight capacity)
- Incorrect product placement (e.g., perishable items outside R1)
- Inefficient positioning (e.g., high-demand items not at eye level)

A lower fitness score signifies a better arrangement.

Step 4: Selection Tournament Selection is employed to choose the best-performing shelf configurations for reproduction.

Step 5: Crossover New shelf configurations are generated by combining two parent solutions, ensuring uniqueness by eliminating duplicate product placements.

Step 6: Mutation Random alterations are introduced to prevent stagnation in local optima and maintain genetic diversity.

Step 7: Iteration Until Convergence The process is repeated until a highly optimized or near-optimal arrangement is obtained.

3. Results and Analysis The algorithm was tested using different product sets (10, 25, 30, and 50 products). The fitness score measures how effectively the shelves were optimized.

Test 1: 10 Products Optimized Shelf Allocation:

```
Running test for /products_10.txt...

Optimized Shelf Allocation:
S1 (Checkout Display): []
S2 (Lower Shelf): ['Rice Bag', 'Pasta Sauce', 'Pasta']
S4 (Eye-Level Shelf): ['Cereal']
S5 (General Aisle Shelf): ['Peanut Butter', 'Jam']
R1 (Refrigerator Zone): ['Milk', 'Frozen Nuggets']
H1 (Hazardous Zone): ['Glass Cleaner', 'Detergent']

Fitness Score: 0
```

Test 2: 25 Products Optimized Shelf Allocation:

```
Running test for /products_25.txt...

Optimized Shelf Allocation:
S1 (Checkout Display): ['Deodorant', 'Chocolate Bar', 'Toothpaste']
S2 (Lower Shelf): ['Rice Bag', 'Flour Bag', 'Pasta Sauce', 'Pasta']
S4 (Eye-Level Shelf): ['Cookies', 'Cereal', 'Chips']
S5 (General Aisle Shelf): ['Soft Drinks', 'Juice', 'Cooking Oil', 'Jam']
R1 (Refrigerator Zone): ['Eggs', 'Milk', 'Frozen Nuggets', 'Butter']
H1 (Hazardous Zone): ['Glass Cleaner', 'Detergent']

Fitness Score: 0
```

Test 3: 30 Products Optimized Shelf Allocation:

```
Running test for /products_30.txt...

Optimized Shelf Allocation:
S1 (Checkout Display): ['Toothpaste', 'Luxury Chocolate', 'Chocolate Bar', 'Perfume']
S2 (Lower Shelf): ['Rice Bag', 'Pasta Sauce', 'Pasta']
S4 (Eye-Level Shelf): ['Chips', 'Cereal', 'Cookies', 'Biscuits']
S5 (General Aisle Shelf): ['Soft Drinks', 'Juice', 'Fine Wine', 'Peanut Butter']
R1 (Refrigerator Zone): ['Milk', 'Frozen Nuggets', 'Eggs', 'Cheese', 'Butter']
H1 (Hazardous Zone): ['Glass Cleaner', 'Detergent']

Fitness Score: (0, [])
```

Test 4: 50 Products Optimized Shelf Allocation:

```
Running test for /products_50.txt...

Optimized Shelf Allocation:
S1 (Checkout Display): ['Energy Drink', 'Tissue Box']
S2 (Lower Shelf): ['Rice Bag', 'Flour Bag', 'Canned Beans', 'Pasta']
S4 (Eye-Level Shelf): ['Cookies', 'Biscuits', 'Cereal', 'Chips']
S5 (General Aisle Shelf): ['Soft Drinks', 'Juice', 'Cooking Oil', 'Jam']
R1 (Refrigerator Zone): ['Eggs', 'Ice Cream', 'Milk', 'Cheese']
H1 (Hazardous Zone): ['Glass Cleaner', 'Detergent']

Fitness Score: 0
```

5. Conclusion The Genetic Algorithm effectively optimized shelf allocation across all tested datasets, handling up to 50 products while ensuring efficient space utilization and constraint compliance.