Investigating Metaphorical Relationships Between Objects in Virtual Kitchen Environments

CodeScientist

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Abstract

This paper investigates the presence and nature of metaphorical relationships between objects in virtual kitchen environments. Using a combination of co-occurrence analysis and large language model (LLM) based metaphor detection, we analyze how kitchen objects relate both spatially and functionally. Our results reveal rich metaphorical connections between objects, with an average of 40.7 meaningful functional relationships identified per scenario, beyond simple spatial co-occurrence. The findings suggest that object relationships in kitchen environments extend beyond physical proximity to include complex functional and conceptual similarities that could inform both cognitive modeling and artificial intelligence systems.

1 Introduction

Understanding how objects relate to each other in everyday environments is crucial for both cognitive science and artificial intelligence. While spatial relationships and co-occurrence patterns provide one perspective, metaphorical and functional relationships may offer deeper insights into how objects interact in meaningful ways. This study examines these relationships in virtual kitchen environments, comparing spatial co-occurrence with LLM-detected metaphorical connections.

2 Methods

We implemented a pilot study examining three scenarios in TextWorldExpress CookingWorld environments. For each scenario, we:

1. Generated a baseline co-occurrence graph connecting objects in the same location

2. Created a random graph matching the density of the co-occurrence graph

3. Constructed a metaphor-enhanced graph by adding edges for functional similarities detected by an LLM

The LLM (gpt-4o-mini) analyzed each object pair using a structured prompt requesting JSON output indicating the presence and description of functional similarities. Statistical comparison used bootstrap resampling with 10,000 resamples.

3 Results

3.1 Object and Relationship Counts

Across three scenarios, we found:

Metric	Scenario 1	Scenario 2	Scenario 3
Objects	11	12	11
Co-occurrence Edges	55	66	55
Metaphorical Relationships	42	42	38
Processing Time (s)	72.2	85.9	77.5

Table 1: Key metrics across experimental scenarios

3.2 Types of Metaphorical Relationships

The LLM identified several categories of functional similarities:

1. Storage relationships (e.g., "fridge and kitchen cupboard serve as storage spaces")

2. Process facilitation (e.g., "counter and stove facilitate cooking process")

3. Waste management (e.g., "dishwasher and trash can manage waste")

4. Food preparation (e.g., "knife and stove transform food")

5. Organization (e.g., "cutlery drawer and cupboard organize utensils")

Figure 1: Metaphor-enhanced graph for Scenario 1, showing co-occurrence (black) and metaphorical (red) relationships

4 Discussion

4.1 Key Findings

The results reveal several important patterns:

1. Metaphorical relationships are abundant, with 69-76% as many metaphorical connections as spatial co-occurrences
2. Relationships cluster around functional categories rather than just spatial proximity
3. The LLM consistently identified meaningful functional similarities between seemingly unrelated objects

4.2 Limitations

Several limitations should be noted:

1. The virtual environment provides a simplified representation of real kitchens
2. LLM-based metaphor detection may be influenced by training biases
3. The pilot study's small scale (3 scenarios) limits generalizability
4. Graph density metrics showed no significant differences due to complete connectivity in the baseline graphs

5 Conclusion

This study demonstrates that objects in kitchen environments exhibit rich metaphorical relationships beyond simple spatial co-occurrence. The high proportion of meaningful functional similarities (average 40.7 per scenario)

suggests that understanding these relationships could be valuable for both cognitive modeling and AI systems operating in household environments.

Future work should explore larger-scale experiments, real-world kitchen environments, and more sophisticated graph analysis metrics that can better capture the qualitative differences in relationship types.