

# Project 1

## An Application of Ontological Concepts, Categories and Relationships on a Knowledge Base of Common Household Items and Analysis with SNARK

### CSE 563: Knowledge Representation & Reasoning

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## Introduction

You can't manage knowledge — nobody can. What you *can* do is to manage the environment in which knowledge can be created, discovered, captured, shared, distilled, validated, transferred, adopted, adapted and applied[1].  
—C. Collison and G. Parcell

The intent of this project is to create an ontology of items that would be typically found in the average household. Essentially, the task is to describe what those household items are, and also to express any relationships that may exist between them. This requires the investigator to define and establish several different types of categories that the items might fall under. Once those categories are defined, it is necessary to make some common sense reasonings as to what type of connections exist between the items and categories.

Items and categories make up the basic foundation of the knowledge base of an ontology. However, it is necessary to impose some sort of logical reasoning on this structure. This means that the common sense relationships that are present among the items and categories, have to be translated into knowledge base rules. However, when devising these rules, there's a certain amount of subjectivity involved, since there's no clear system of methodology for creating them. I believe that this is something of an advantage, because there's no upper bound on how detailed and intricate an ontology can become.

Once the knowledge base rules have been formalized, it is possible to submit general queries about the items that exist in the ontology. In this project, the software language `Lisp` is used, and the package that handles the knowledge base computations is called `SNARK`(SRI's New Automated Reasoning Kit) [2].

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# 1 Domain

According to the project scope[3], our initial task was to establish the structure of the knowledge base, that is, to define the sorts of items that would populate the knowledge base domain. I had decided that, in general, the items would consist mainly of various appliance types, as well as a wide range of electronics goods. Much of my research focused on the websites of major consumer retail chains. In the case of the appliances, I examined the online catalogs for Ikea[4] and Lowe's[6]. My research for the electronics category was based on items from the popular retail chain Best Buy[5]. I selected items which were rich in diversity, so that they could be easily expressed under multiple categories.

## 2 Formalism

In this section, I provide a description of the atomic propositions, as well as a detailed formulation of the knowledge base rules.

### 2.1 An Overview of the Syntax and Intensional Semantics of the Atomic Propositions

Here is a layout of the atomic propositions in the knowledge base, ordered alphabetically.

1. [Amplifier] = It's an amplifier.
2. [Appliance] = It's an appliance.
3. [Audio] = It's an audio item.
4. [BestBuyComputerPeripheral] = It's a Best Buy computer peripheral.
5. [BestBuyDigitalCamera] = It's a Best Buy digital camera.
6. [BestBuyMP3Player] = It's a Best Buy mp3 player.
7. [BestBuyPrinter] = It's a Best Buy printer.
8. [BluRayPlayer] = It's a Blu-ray player.
9. [CDPlayer] = It's a CD player.
10. [Computer] = It's a computer item.
11. [Desktop] = It's a desktop computer.
12. [DVDPlayer] = It's a DVD player.
13. [Electronic] = It's an electronic item.
14. [FM] = It's an FM radio.
15. [Headphones] = It's headphones.
16. [HouseholdItem] = It's a household item.
17. [IkeaAppliance] = It's an Ikea appliance.
18. [IkeaBlender] = It's an Ikea blender.

19. [IkeaDishwasher] = It's an Ikea dishwasher.
20. [KitchenAppliance] = It's a kitchen appliance.
21. [Laptop] = It's a laptop computer.
22. [LargeAppliance] = It's a large appliance.
23. [LowesDryer] = It's a Lowe's dryer.
24. [LowesLaundryAppliance] = It's a Lowe's laundry appliance.
25. [LowesLaundryMachine] = It's a Lowe's laundry machine.
26. [Microphone] = It's a microphone.
27. [Netbook] = It's a netbook computer.
28. [PowerDrill] = It's a power drill.
29. [Radio] = It's a radio.
30. [Satellite] = It's a satellite radio.
31. [SmallAppliance] = It's a small appliance.
32. [Speakers] = It's speakers.
33. [StereoSystem] = It's a stereo system item.
34. [Toaster] = It's a toaster.
35. [TV] = It's a TV.
36. [Video] = It's a video item.

## 2.2 A Formal Presentation of the Knowledge Base Information

In this section, I present a detailed listing of the information in the `HouseholdItem` knowledge base, as well as a graphical representation of the ontology. Each entry has a simple description in English, followed by its respective assertion statement in SNARK format.

### 2.2.1 Implication Statements

The following statements establish the relationships between subclasses and their respective superclasses. In general, each one of these implication statements corresponds to an arrow in Figure 1.

1. If it's an appliance, then it's a household item.

```
(assert '(=> Appliance HouseholdItem))
```

2. If it's an electronic item, then it's a household item.

```
(assert '(=> Electronic HouseholdItem))
```

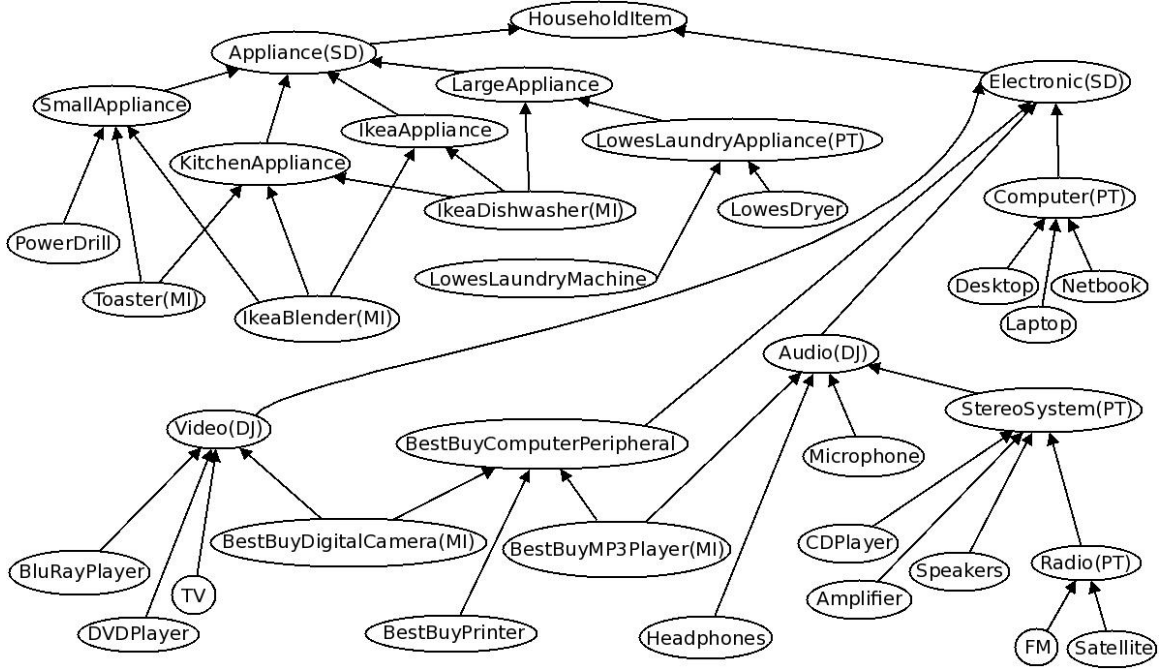


Figure 1: A graphical representation of the HouseholdItem ontology. Brackets indicate the following knowledge base aspects: MI=multiple inheritance, DJ=disjoint categories, PT=partitions, SD=sufficient depth.

3. If it's a small appliance, then it's an appliance.

```
(assert '(=> SmallAppliance Appliance))
```

4. If it's a kitchen appliance, then it's an appliance.

```
(assert '(=> KitchenAppliance Appliance))
```

5. If it's an Ikea appliance, then it's an appliance.

```
(assert '(=> IkeaAppliance Appliance))
```

6. If it's a large appliance, then it's an appliance.

```
(assert '(=> LargeAppliance Appliance))
```

7. If it's a power drill, then it's a small appliance.

```
(assert '(=> PowerDrill SmallAppliance))
```

8. If it's an Ikea blender, then it's a small appliance and a kitchen appliance and an Ikea appliance.

```
(assert '(=> IkeaBlender
  (and SmallAppliance KitchenAppliance IkeaAppliance)))
```

9. If it's a toaster, then it's a small appliance and a kitchen appliance.

- (assert '(=> Toaster (and SmallAppliance KitchenAppliance)))
10. If it's an Ikea dishwasher, then it's a kitchen appliance and an Ikea appliance and a large appliance.
- (assert '(=> IkeaDishwasher  
(and KitchenAppliance IkeaAppliance LargeAppliance)))
11. If it's a Lowe's laundry appliance, then it's a large appliance.
- (assert '(=> LowesLaundryAppliance LargeAppliance))
12. If it's a Lowe's laundry machine, then it's a Lowe's laundry appliance.
- (assert '(=> LowesLaundryMachine LowesLaundryAppliance))
13. If it's a Lowe's Dryer, then it's a Lowe's laundry appliance.
- (assert '(=> LowesDryer LowesLaundryAppliance))
14. If it's a video item, then it's an electronic item.
- (assert '(=> Video Electronic))
15. If it's a Best Buy computer peripheral, then it's an electronic item.
- (assert '(=> BestBuyComputerPeripheral Electronic))
16. If it's an audio item, then it's an electronic item.
- (assert '(=> Audio Electronic))
17. If it's a computer item, then it's an electronic item.
- (assert '(=> Computer Electronic))
18. If it's a Blu-Ray player, then it's a video item.
- (assert '(=> BluRayPlayer Video))
19. If it's a DVD player, then it's a video item.
- (assert '(=> DVDPlayer Video))
20. If it's a TV, then it's a video item.
- (assert '(=> TV Video))
21. If it's a Best Buy digital camera, then it's a video item and a BestBuyComputerPeripheral.
- (assert '(=> BestBuyDigitalCamera (and Video BestBuyComputerPeripheral)))

22. If it's a Best Buy printer, then it's a Best Buy computer peripheral.

```
(assert '(=> BestBuyPrinter BestBuyComputerPeripheral))
```

23. If it's a Best Buy mp3 player, then it's a Best Buy computer peripheral and an audio item.

```
(assert '(=> BestBuyMP3Player (and BestBuyComputerPeripheral Audio)))
```

24. If it's headphones, then it's an audio item.

```
(assert '(=> Headphones Audio))
```

25. If it's a microphone, item then it's an audio item.

```
(assert '(=> Microphone Audio))
```

26. If it's a stereo system, then it's an audio item.

```
(assert '(=> StereoSystem Audio))
```

27. If it's a desktop computer, then it's a computer item.

```
(assert '(=> Desktop Computer))
```

28. If it's a laptop computer, then it's a computer item.

```
(assert '(=> Laptop Computer))
```

29. If it's a netbook computer, then it's a computer item.

```
(assert '(=> Netbook Computer))
```

30. If it's a CD player, then it's a stereo system item.

```
(assert '(=> CDPlayer StereoSystem))
```

31. If it's an amplifier, then it's a stereo system item.

```
(assert '(=> Amplifier StereoSystem))
```

32. If it's speakers, then it's a stereo system item.

```
(assert '(=> Speakers StereoSystem))
```

33. If it's a radio, then it's a stereo system item.

```
(assert '(=> Radio StereoSystem))
```

34. If it's an FM radio, then it's a radio item.

```
(assert '(=> FM Radio))
```

35. If it's a satellite radio, then it's a radio item.

```
(assert '(=> Satellite Radio))
```

### 2.2.2 Mutual Disjointness Rule

The following is a knowledge base rule for nodes with a distance of 1 from the root. In the `HouseHoldItem` ontology, there are two of these nodes: `Appliance` and `Electronic`. This rule introduces mutual disjointness into the entire knowledge base.

1. If it's an Appliance, then it's not an Electronic item.

```
(assert '(=> Appliance (not Electronic)))
```

### 2.2.3 Exhaustiveness Rules

The following are knowledge base rules for categories which exhibit exhaustiveness.

1. It's a radio if and only if it's a FM radio or a satellite radio.

```
(assert '(<=> Radio (or FM Satellite)))
```

2. It's a stereo system if and only if it's a CD player or amplifier or speakers or radio.

```
(assert '(<=> StereoSystem (or CDPlayer Amplifier Speakers Radio)))
```

3. It's a computer if and only if it's a desktop computer or a laptop computer or a netbook computer.

```
(assert '(<=> Computer (or Desktop Laptop Netbook)))
```

4. It's a Lowe's laundry appliance if and only if it's a Lowe's laundry machine or a Lowe's dryer.

```
(assert '(<=> LowesLaundryAppliance (or LowesLaundryMachine LowesDryer)))
```

## 3 Program Demonstration and Discussion

In this section, I provide software code, program output, and an interpretation of the results.

### 3.1 Testing the transitivity of the subclass relation: $A \Rightarrow B$

#### 3.1.1 SNARK query

The question posed to SNARK is, "If it's a power drill, is it an appliance?"

```
(query "Ask if 'PowerDrill implies Appliance'
      is logically entailed. (True.)"
      '(=> PowerDrill Appliance))
```

#### 3.1.2 SNARK evaluation output

```
Ask if 'PowerDrill implies Appliance'
      is logically entailed. (True.)
(ask '(=> PowerDrill Appliance)) = True
```

### 3.1.3 Informal explanation of reasoning

If it's a power drill, then it's a small appliance. If it's a small appliance, then it's an appliance. Therefore, if it's a power drill, then it's an appliance.

## 3.2 Testing the transitivity of the subclass relation: $A_1 \vee \dots \vee A_n \Rightarrow B$

**Note:**  $A_i$  is an immediate subcategory of at least two different categories.

### 3.2.1 SNARK query

The question posed to SNARK is, "If it's a Blu-ray player or a Best Buy printer or a microphone, is it an electronic item?"

```
(query
  "Ask if 'BluRayPlayer or BestBuyPrinter or Microphone
  implies Electronic' is logically entailed. (True.)"
  '(=> (or BluRayPlayer BestBuyPrinter Microphone) Electronic))
```

### 3.2.2 SNARK evaluation output

```
Ask if 'BluRayPlayer or BestBuyPrinter or Microphone
  implies Electronic' is logically entailed. (True.)
(ask '(=> (or BluRayPlayer BestBuyPrinter Microphone) Electronic)) = True
```

### 3.2.3 Informal explanation of reasoning

If it's a Blu-ray player, then it's an electronic item. If it's a Best Buy printer, then it's an electronic item. If it's a microphone, then it's an electronic item. Therefore, if it's a Blu-ray player or a Best Buy printer or a microphone, then it's an electronic item.

## 3.3 Testing the mutual disjointness of some classes: $A \Rightarrow \neg B$

### 3.3.1 SNARK query

The question posed to SNARK is, "If it's a video item, is it an Ikea appliance?"

```
(query
  "Ask if 'Video implies not IkeaAppliance'
  is logically entailed. (True.)"
  '(=> Video (not IkeaAppliance)))
```

### 3.3.2 SNARK evaluation output

```
Ask if 'Video implies not IkeaAppliance'
  is logically entailed. (True.)
(ask '(=> Video (not IkeaAppliance))) = True
```

### 3.3.3 Informal explanation of reasoning

If it's a video item, then it's a Blu-ray player or a DVD player or a TV or a Best Buy digital camera. If it's an Ikea appliance, then it's an Ikea blender or an Ikea dishwasher. Therefore, if it's a video item, then it's not an Ikea appliance.



### 3.4 Testing the exhaustiveness of some subcategories: $A \Rightarrow B_1 \vee \dots \vee B_n$

#### 3.4.1 SNARK query

The question posed to SNARK is, “If it’s a radio, is it an FM radio or a satellite radio?”

```
(query
  "Ask if ‘‘Radio implies FM or Satellite’’
  is logically entailed. (True.)"
  '(=> Radio (or FM Satellite)))
```

#### 3.4.2 SNARK evaluation output

```
Ask if ‘‘Radio implies FM or Satellite’’
  is logically entailed. (True.)
(ask '(=> Radio (or FM Satellite))) = True
```

#### 3.4.3 Informal explanation of reasoning

If it’s an FM radio, then it’s a radio. If it’s a satellite radio, then it’s a radio. Therefore, if it’s a radio, then it’s an FM radio or a satellite radio.

### 3.5 Testing the exhaustiveness of some subcategories: $A \wedge \neg B_1 \wedge \dots \wedge \neg B_n \Rightarrow C$

#### 3.5.1 SNARK query

The question posed to SNARK is, “If it’s a desktop computer and not a laptop computer and not a netbook computer, is it a computer?”

```
(query
  "Ask if ‘‘Desktop and ~Laptop and ~Netbook
  implies Computer’’ is logically entailed. (True.)"
  '(=> (and Desktop (not Laptop) (not Netbook)) Computer))
```

#### 3.5.2 SNARK evaluation output

```
Ask if ‘‘Desktop and ~Laptop and ~Netbook
  implies Computer’’ is logically entailed. (True.)
(ask '(=> (and Desktop (not Laptop) (not Netbook)) Computer)) = True
```

#### 3.5.3 Informal explanation of reasoning

If it’s a desktop computer, it’s not a laptop computer. Also, if it’s a desktop computer, it’s not a netbook computer. Therefore, if it’s a desktop computer, it’s a computer.

### 3.6 Testing a relation for which the answer is Unknown

#### 3.6.1 SNARK query

The question posed to SNARK is, “If it’s a kitchen appliance, is it an Ikea blender?”

```
(query
  "Ask if 'KitchenAppliance implies IkeaBlender'
  is logically entailed. (Unknown.)"
  '(=> KitchenAppliance IkeaBlender))
```

### 3.6.2 SNARK evaluation output

```
Ask if 'KitchenAppliance implies IkeaBlender'
  is logically entailed. (Unknown.)
(ask '(=> KitchenAppliance IkeaBlender)) = Unknown
```

### 3.6.3 Informal explanation of reasoning

If it's a kitchen appliance, then it's a toaster or an Ikea blender or an Ikea dishwasher. Therefore, if it's a kitchen appliance, then there are several different models that satisfy the wfp, and hence the relation is Unknown.

## 3.7 Program discussion

For this project, the knowledge base consisted of items, categories, and the relationships that existed between them. The vast majority of the knowledge base rules were simple implication statements. From this relatively basic foundation, I was able to prove important logical properties such as transitivity, disjointness and exhaustiveness.

## Acknowledgements

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## References

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