CS 6364: Artificial Intelligence

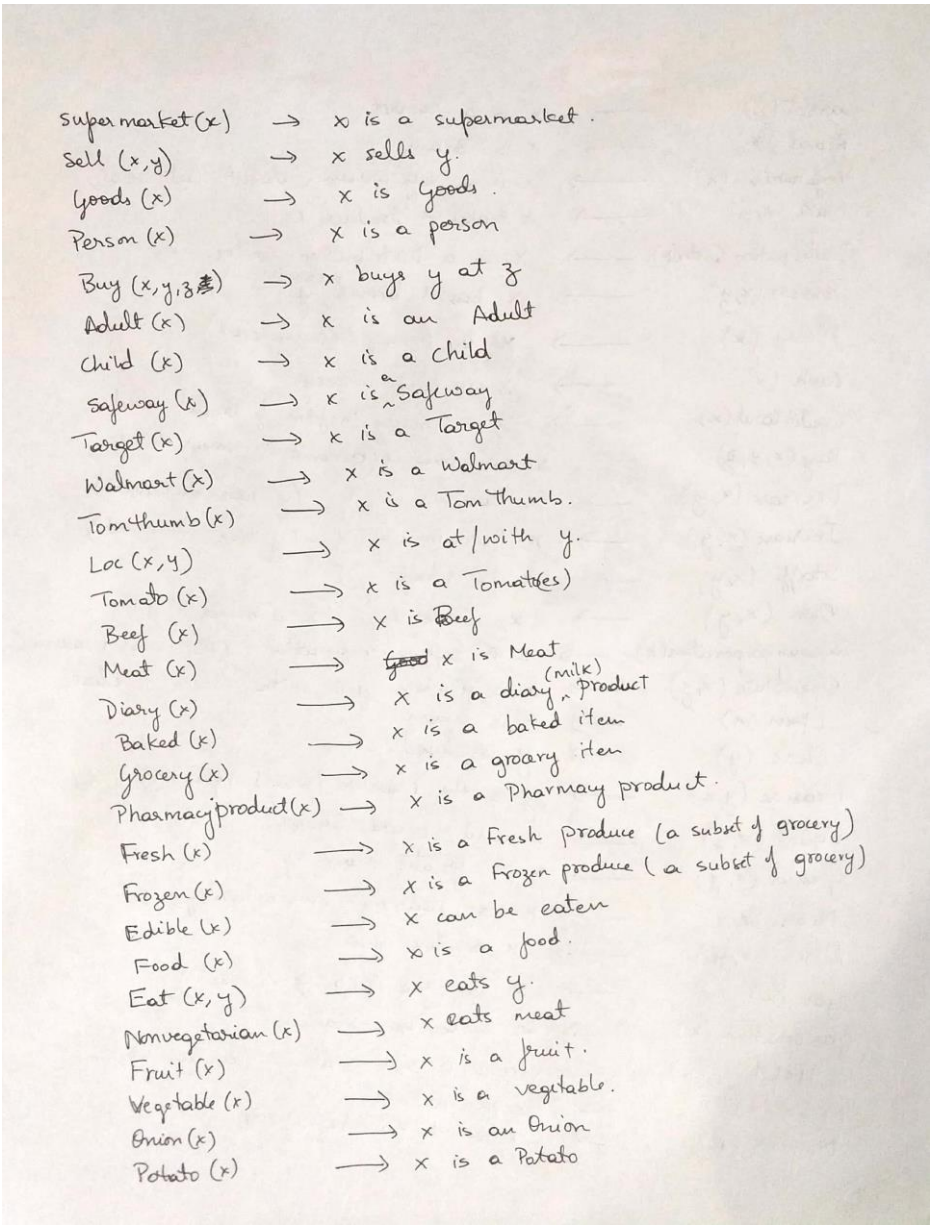
Project: Supermarket Knowledge Base

Problem Statement:

To design and create a knowledge base in Prover9 for shopping at a supermarket, that captures enough knowledge to answer a series of questions about this domain

Knowledge Base description:

The knowledge Base constructed contains about 90 predicates as shown in the images below:



Carrot (x) ⟶ x is a Carrot

Beans (x) ⟶ x is Beans.

Vegetarian (x) ⟶ x is a Vegetarian (doesn't eat meat)

Make (x, y) ⟶ x makes or produces y

Distribution Centre(x) ⟶ x is a Distribution Centre.

Possess (x, y) ⟶ x has or brings or carries y

Money (x) ⟶ x is Money (in general)

Cash (x) ⟶ x is cash money.

Credit Card (x) ⟶ x is money in form of credit card.

Pay (x, y, z) ⟶ x has paid y (amount of money) to z

Decrease (x, y) ⟶ x has less of y. (y has decreased)

Increase (x, y) ⟶ x has more of y. (y has increased)

Staff (x, y) ⟶ x is staff of y.

Own (x, y) ⟶ x owns y. (x is owner of y)

Safeway corporation (x) ⟶ x is Safeway corporation (the owner of safeway)

OpenState (x, y) ⟶ x is y where y is either open or close.

Open (x) ⟶ x is open

Close (y) ⟶ y is closed.

Measure (y, x) ⟶ y is the Measure (weight or quantity) of x.

Equal (x, y) ⟶ x and y are Equal.

Greater (x, y) ⟶ x is greater than y.

Near (x, y) ⟶ x is nearby (geographically) y.

Lesser (x, y) ⟶ x is less than y.

Gas (x) ⟶ x is gas (petrol or fuel)

Gas station (x) ⟶ x is a gas-station.

Shellstation (x) ⟶ x is a shell station (a gas station)

Weight (x) ⟶ x is weight.

Number (x) ⟶ x is the number of items.

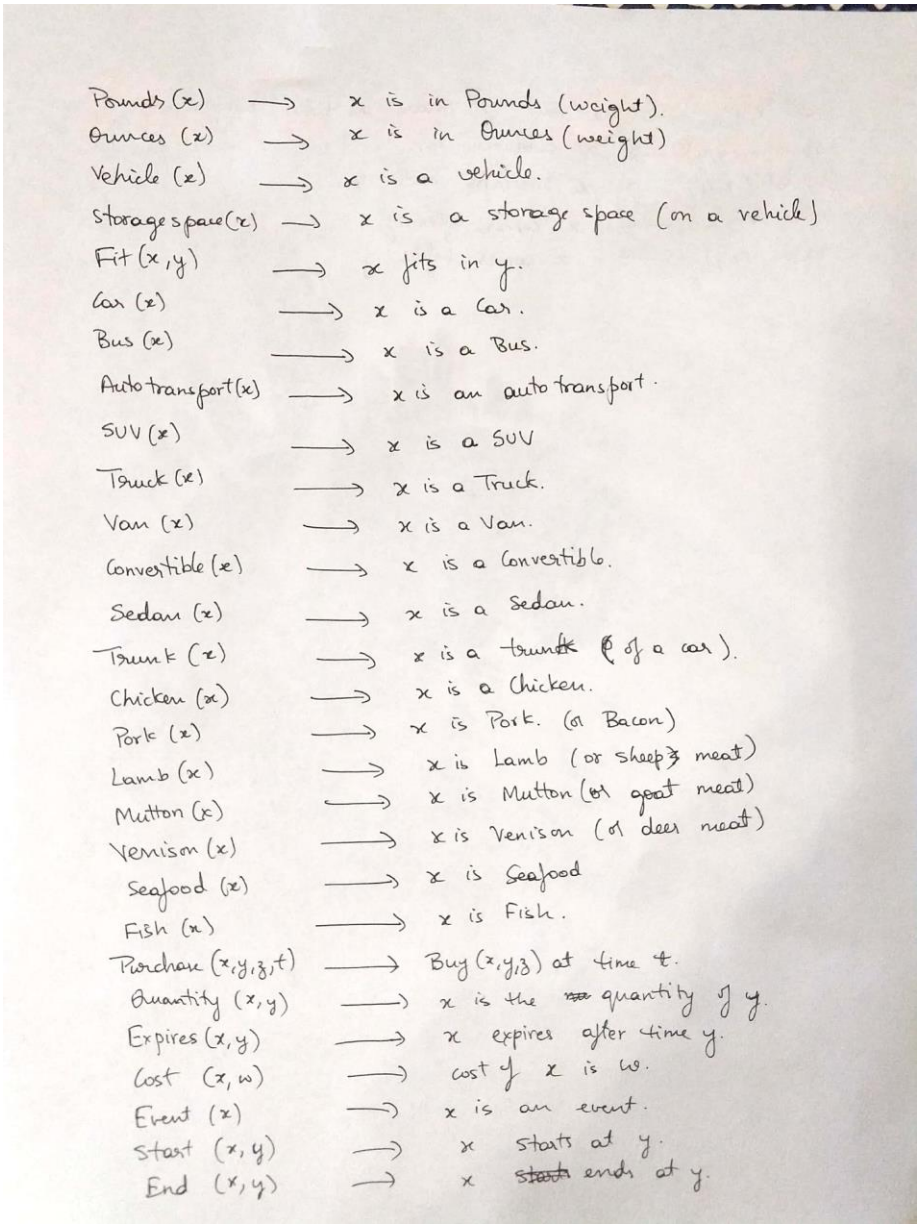
Share (x, y) ⟶ x and y share a time period.

Subsumes (x, y) ⟶ x subsumes y.

Overlap (x, y) ⟶ x overlaps with y.

After (x, y) ⟶ x comes after y

Before (x, y) ⟶ x comes before y.



This Knowledge base tries to answer the questions raised in problem 12.5 and 12.6 of the textbook "Artificial Intelligence: A Modern Approach, *Third edition*". I have tried to capture the situations and events listed in these questions. In Prover9, as we prove or conclude something by resolution refutation, the questions need to be asked as goals which Provr9 can verify by negating and checking against the Knowledge Base.

This knowledge base covers activities where people buy goods from supermarket, them having to pay for the goods to buy, that they need to have money to pay and such. This KB assumes that everything that is goods is available at a supermarket.

Few predicates have hierarchies – for example Tomato is a fruit, a fruit is a fresh produce, a fresh produce is a grocery, grocery is goods.

This Knowledge base was built to answer the below questions:

Q1) Is John a child or an adult?

Q2) Does John now have at least two tomatoes?

Q3) Did John buy any meat?

Q4) If Mary was buying tomatoes at the same time as John, did he see her?

Q5) Are the tomatoes made in the supermarket?

Q6) What is John going to do with the tomatoes?

Q7) Does Safeway sell deodorant?

Q8) Did John bring some money or a credit card to the supermarket?

Q9) Does John have less money after going to the supermarket?

Q10) Are there other people in Safeway while John is there?

Q11) Is John a vegetarian?

Q12) Who owns the deodorant in Safeway?

Q13) Did John have an ounce of ground beef?

Q14) Does the Shell station next door have any gas?

Q15) Do the tomatoes fit in John's car trunk?

I have tested the Knowledge base against these questions. The questions were modelled as below:

Q1) Adult(John).

Q2) Person(John) & Tomato(x) & Number(2) & Measure(2,w).

Q3) Buy(John,x,y) & Meat(x).

Q4) Person(Mary) & Buy(Mary,x,z) & Tomato(x) & NorthBerkeleySafeway(z) & Share(John,Mary) -> Meet(John,Mary).

Q5) Tomato(x) & -Make(y,x) & Supermarket(y).

Q6) Tomato(x) & Eat(John, x).

Q7) Sell(x,Deodarant) & Safeway(x).

Q8) Possess(John,y) & Money(y).

Q9) Decrease(John,x) & Money(x).

Q10) -Loc(John,x) | -Supermarket(x) | -Staff(z,x) | Loc(z,x).

Q11) Nonvegetarian(John).

Q12) Safeway(x) & Goods(Deodarant) & Possess(x, Deodarant) -> Own(x,Deodarant).

Q14) Shellstation(x) & Possess(x,y) -> Gas(y).

Prover9 was able to give a proof for the above test cases using resolution refutation. The proof for few are included in separate files named as input_Q*.proof where * is replaced by the question numbers.

Knowledge Base Axioms:

- supermarket sell all goods
- Adults buy goods at a supermarket.
- People can be Adults or child
- Safeway is a supermarket
- Target is a supermarket
- Walmart is a supermarket
- Tam thumb is a supermarket
- North Berkeley Safeway is a Safeway
- North Berkeley Safeway is in North Berkeley
- Meat, dairy, baked items, grocery and pharmacy products are goods that are available in a supermarket
- Groceries consists of fresh and frozen produce.
- Goods that are edible are food
- If anything is edible, then it can be eaten by people
- Meat is a food
- Groceries is food
- Diary is food
- People eat food
- People who eat meat are non-vegetarians
- beef is meat.
- Fruits are groceries
- Vegetables are grocery
- Tomato is a fruit
- Onion is a vegetable
- Potato is a vegetable
- Carrot is a vegetable
- Beans is a vegetable
- Vegetarians do not eat meat
- People only buy edible goods that they eat
- Supermarket does not make anything
- Supermarkets buys goods from Distribution centres
- Anyone can buy anything at supermarket (Supermarket sells everything)
- People need to bring money to buy goods at supermarket
- Money can be cash or credit card
- People need to pay to buy goods at the supermarket
- People need to have money to pay
- People have less money after paying

- Decrease in anything indicates not increase and increase in anything indicates not decrease (they are inverse of the other)
- Staff of supermarket are Adult
- Supermarket is owned by an adult
- All the items in a supermarket is owned by the supermarket
- Owning anything is transitive
- Safeway is owned by Safeway Corporations
- Staff are always at supermarket when it is open
- People can only go to supermarket when it is open
- When anything is open it is not closed, when it is closed it is not open
- Goods are purchased in weight or numbers
- At supermarkets, the unit of weight used is pound
- Pound is greater than ounces (1 pound is 16 ounces)
- Supermarkets have gas station near them
- Gas stations have gas
- Shell station is a gas station
- People only buy goods that fit in the vehicle storage space
- All vehicles have storage spaces
- Car is a vehicle
- Bus is a vehicle
- Train is a vehicle
- SUV is a type of car
- Truck is a type of car
- Van is a type of car
- Convertible is a type of car
- Sedan is a type of car
- In a car, trunk is the storage space
- Chicken is meat
- Pork is meat
- Lamb is meat
- Mutton is meat
- Venison is meat
- Sea food is meat
- Fish is sea food
- People buying an item at the same time in a supermarket meet each other
- People who never bought the same item at the same time do not meet
- n pound of tomatoes has at least n tomatoes
- n pound of Onion has at least n onion
- n pound of potato has at least n potato
- Meat products have an expiry date after purchase
- Supermarkets have aisles for goods
- Each goods has a price tag associated with it
- People have to pay the money shown in the price tag to purchase the goods
- Every visit to supermarket has a start time and end time
- Two events share a time period if the second event starts before the first ends
- If two events share a time period then they overlap

- If one event subsumes another then the smaller event occurs during the larger event
- Event end time is always greater than start time
- If one event starts after another ends then former occurs after.
- If an event occurs after an event then the latter event occurs before the former
- If one event occurs after another event then they do not meet
- If one event occurs before another event then they do not meet
- If two events overlap then they meet
- if anything is greater than another thing then it implies the latter is less than the former.
- If one event subsumes another, then they meet
- if anything is less than another thing then it implies the latter is greater than the former.
- If anything is less than another then it implies the latter is not less than the former
- If anything is greater than another then it implies the latter is not greater than the former
- If anything is near another thing then it implies that the latter is also near the former thing.
- If the goods fit in the storage space of a vehicle then it implies they fit in the vehicle.
- Aisles have shelves
- Adults are not children, children are not adults
- Fresh produce is not frozen produce, frozen is not fresh
- Vegetarians are not non-vegetarians, non-vegetarians are not vegetarians
- John went to the North Berkeley Safeway supermarket and bought two pounds of tomatoes and a pound of ground beef.

Knowledge Base First Order Logic Sentences:

The universal quantifiers have been omitted but existential quantifiers are retained in these sentences.

- (Supermarket(x) & Sell(x,y)) -> Goods(y).
- (Person(x) & Goods(y) & Supermarket(z) & Buy(x,y,z)) -> Adult(x).
- Person(x) -> (Adult(x) | Child(x)).
- Target(x) -> Supermarket(x).
- Walmart(x) -> Supermarket(x).
- Tomthumb(x) -> Supermarket(x).
- Safeway(x) -> Supermarket(x).
- NorthBerkeleySafeway(x) -> Safeway(x).
- NorthBerkeleySafeway(x) -> Loc(x, NorthBerkeley).
- Meat(x) -> Goods(x).
- Diary(x) -> Goods(x).
- Baked(x) -> Goods(x).
- Grocery(x) -> Goods(x).
- Pharmacyproduct(x) -> Goods(x).
- Grocery(x) -> (Fresh(x) | Frozen(x)).
- (Goods(x) & Edible(x)) -> Food(x).
- (Edible(x) & Person(y)) <-> Eat(y,x).
- Meat(x) -> Food(x).
- Grocery(x) -> Food(x).
- Diary(x) -> Food(x).

- (Person(x) & Food(y)) -> Eat(x,y).
- (Person(x) & Meat(y) & Eat(x,y)) -> Nonvegetarian(x).
- Beef(x) -> Meat(x).
- Fruit(x) -> Grocery(x).
- Fruit(x) -> Fresh(x).
- Vegetable(x) -> Fresh(x).
- Vegetable(x) -> Grocery(x).
- Tomato(x) -> Fruit(x).
- Onion(x) -> Vegetable(x).
- Potato(x) -> Vegetable(x).
- Carrot(x) -> Vegetable(x).
- Beans(x) -> Vegetable(x).
- (Meat(x) & Person(y) & -Eat(y,x)) -> Vegetarian(y).
- (Person(x) & Goods(y) & Edible(y) & Buy(x,y,z)) -> Eat(x,y).
- Supermarket(x) -> -Make(x,y).
- (Supermarket(x) & Buy(x,y,z) & Goods(y)) -> Distributioncentre(z).
- (Person(x) & Supermarket(y)) -> Buy(x,z,y).
- (Person(x) & Buy(x,y,z) & Supermarket(z) & Goods(y)) -> (Possess(x,w) & Money(w)).
- Money(x) -> (Cash(x) | Creditcard(x)).
- (Person(x) & Buy(x,y,z) & Goods(y) & Supermarket(z)) -> (Pay(x,w,z) & Money(w)).
- (Person(x) & Pay(x,y,z) & Money(y)) -> Possess(x,y).
- (Person(x) & Pay(x,y,z) & Money(y)) -> Decrease(x,y).
- Decrese(x,y) -> -Increase(x,y).
- Increase(x,y) -> -Decrease(x,y).
- (Person(x) & Staff(x,y) & Supermarket(y)) -> Adult(x).
- (Supermarket(x) & Own(y,x)) -> Adult(x).
- (Goods(x) & Possess(y,x) & Supermarket(y)) -> Own(y,x).
- (Own(x,y) & Own(y,z)) -> Own(x,z).
- (Safeway(x) & Own(y,x)) -> Safewaycorporation(y).
- (Supermarket(x) & Openstate(x,y) & Open(y) & Staff(z,x)) ->(Adult(z) & Loc(z,x)).
- (Person(x) & Supermarket(y) & Loc(x,y)) -> (Openstate(y,z) & Open(z)).
- Openstate(x,y) -> (Open(y) | Close(y)).
- Open(x) -> -Close(x).
- Close(x) -> -Open(x).
- (Goods(x) & Measure(y,x)) -> (Weight(y) | Number(y)).
- Weight(x) -> Pounds(x).
- (Pounds(x) & Ounces(y)) -> Greater(x,y).
- (Supermarkets(x) & Gasstations(y)) -> Near(x,y).
- (Person(x) & Gasstation(y) & Buy(x,z,y)) -> Gas(z).
- (Gasstation(x) & Possess(x,y)) -> Gas(y).
- Shellstation(x) -> Gasstation(x).
- ((Vehicle(x) & Storagespace(y) & Possess(x,y) & Goods(z) & Person(w) & Own(w,x) & Buy(w,z,v)) -> Fit(z,y)).
- all x exists y(Vehicle(x) -> (Possess(x,y) & Storagespace(y))).
- Car(x) -> Vehicle(x).
- Bus(x) -> Vehicle(x).

- Autotransport(x) -> Vehicle(x).
- Suv(x) -> Car(x).
- Truck(x) -> Car(x).
- Van(x) -> Car(x).
- Convertible(x) -> Car(x).
- Sedan(x) -> Car(x).
- (Car(x) & Storagespace(y) & Possess(x,y)) -> Trunk(y).
- Chicken(x) -> Meat(x).
- Pork(x) -> Meat(x).
- Lamb(x) -> Meat(x).
- Mutton(x) -> Meat(x).
- Venison(x) -> Meat(x).
- Seafood(x) -> Meat(x).
- Fish(x) -> Seafood(x).
- all x all y all z all w exists u ((Person(x) & Purchase(x,y,z,u) & Person(w) & Purchase(w,y,z,u)) -> Meet(x,w)).
- (Person(x) & Purchase(x,y,z,u) & Person(w) & -Purchase(w,y,z,u)) -> -Meet(x,w).
- (Tomato(x) & Measure(y,x) & Pounds(y) & Quantity(z,y)) -> (Number(z) & Measure(z,x)).
- (Onion(x) & Measure(y,x) & Pounds(y) & Quantity(z,y)) -> (Number(z) & Measure(z,x)).
- (Potato(x) & Measure(y,x) & Pounds(y) & Quantity(z,y)) -> (Number(z) & Measure(z,x)).
- Meat(x) -> Expires(x,y).
- all x all y exists z ((Supermarket(x) & Goods(y)) -> (Aisle(z) & Loc(y,z))).
- ((Goods(x) & Buy(y,x,z) & Pay(y,w,z)) -> (Money(w) & Cost(x,w))).
- all x exists y (Goods(x) -> Cost(x,y)).
- (Person(x) & Goods(y) & Cost(y,z) & Buy(x,y,w)) -> Pay(x,z,w).
- all x all y all z ((Person(x) & Supermarket(y) & Visit(z,x,y) & Event(z)) -> ((exists u (Start(z,u))) & (exists v (End(z,v))))).
- (Share(x,y) & Start(x,z) & End(x,w) & Start(y,u) & End(y,v)) -> ((Greater(w,u) | Greater(v,z)) & -After(x,y) & -Before(x,y)).
- Share(x,y) -> Overlap(x,y).
- (Subsumes(x,y) & Start(x,u) & End(x,z) & Start(y,v) & End(y,w)) -> (Greater(v,u) & Greater(z,w)).
- (Start(x,u) & End(x,v)) -> Greater(v,u).
- (Start(x,u) & End(y,v) & Greater(u,v)) -> After(x,y).
- After(x,y) -> Before(y,x).
- After(x,y) -> -Meet(x,y).
- Before(x,y) -> -Meet(x,y).
- Overlap(x,y) -> Meet(x,y).
- Greater(x,y) -> Lesser(y,x).
- Lesser(x,y) -> Greater(y,x).
- Greater(x,y) -> -Greater(y,x).
- Lesser(x,y) -> -Lesser(y,x).
- Near(x,y) -> Near(y,x).
- (Fit(x,y) & Goods(x) & Storagespace(y) & Vehicle(z) & Possess(z,y)) -> Fit(x,z).
- all x exists y (Aisle(x) -> Shelves(y)).
- Meet(x,y) -> Meet(y,x).

- Overlap(x,y) -> Overlap(y,x).
- Adult(x) -> -Child(x).
- Child(x) -> -Adult(x).
- Person(John).
- (Tomato(x) & Buy(John, x, y) & NorthBerkeleySafeway(x)).
- (Beef(x) & Buy(John, x, y) & NorthBerkeleySafeway(x)).

Conclusion:

This knowledge base , though not perfect, can answer certain questions about the activities in supermarket.

The knowledge base can be improved upon by adding other activities and transactions to it like returning of an item, existence of Billing counters, Goods that are not available, Goods that are exclusive to certain supermarkets etc.