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# Who owns the zebra and who drinks water?

# Programming in Logic

WOSSAT, Thursday 18th July 2019

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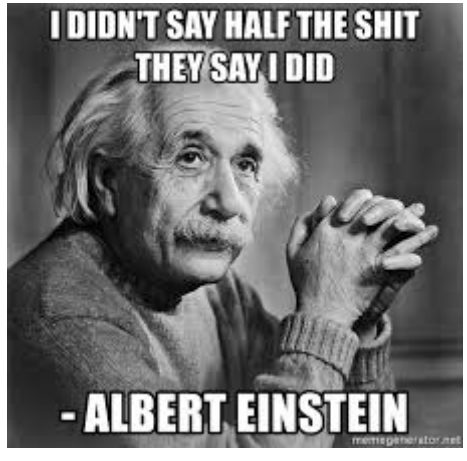
# Einstein's Riddle

(allegedly)


I DIDN'T SAY HALF THE SHIT
THEY SAY I DID
- ALBERT EINSTEIN
memegenerator.net

# There are five houses.

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Who owns the **zebra** and who drinks **water**?

# Prolog

*Programmation en logique*

*"The offspring of a successful marriage between natural language processing and automated theorem-proving."*

# 1971

The result of french research into machine natural language processing.

*"The idea of using a natural language like French to reason and communicate directly with a computer seemed like a crazy idea"*

# Formal logic

The mathematical discipline of formal logic in 4 easy steps

1. Distill problem to notation
2. Apply rules of inference
3. ???
4. ~~Profit~~ Proof!

C+

*If it is raining, then it's cloudy.*

$$P \implies Q$$

*It is raining.*

$$P$$

*Therefore, it's cloudy.*

$$\therefore Q$$

Intuitively, we understand this **argument** is **valid**

The mathematical **discipline** of formal logic

1. Distill problem to notation
2. Apply rules of inference
3. ???
4. ~~Profit~~ Proof!

**Predicate logic** introduces a few more important concepts

# Universal Quantification

*For all* $x$

$$\forall x$$

# Existential Quantification

*There exists some $x$*

$$\exists x$$

# Predicates

*$x$ is $C$ool*

$$Cx$$

*$x$ is $A$djacent to $y$*

$$Axy$$

Notice the prefix notation

Using these constructs of predicate logic we can start to model the real world in logic

# *The englishman Lives in the red house*

*Ler*

Finally, we can also combine **quantifiers** and **predicates**

*There exists some $x$ such that $x$ $L$ives*

*in the $r$ed house*

$$\exists x L x r$$

We are ready to write our first prolog program!

# Prolog

Programs consist of

**facts** and **rules**

Generically, these are referred to as **clauses**

# Our first **fact**

```
human(simon).
```

$$simon\ is\ Human$$

$$Hs$$

# Our first **query**

- **queries** start with ?-
- evaluated as **True**, or **False**

```
?-human(simon).
True
```

# Using **variables** in our **queries**

```
?-human(X).
```

*Does there exist some $x$ such that $x$ is $Human$?*

$$\exists x Hx$$

Prolog look through **facts** it knows about for one that makes the query **True**

Yes!

```
?-human(X).
X=simon
```

$$simon\ is\ Human$$

$$Hs$$

# Family trees

*The FizBuzz of Prolog*

```
father(jamie, tommen).
father(jamie, myrcella).
father(jamie, joffrey).
```

```
mother(cersei, tommen).
mother(cersei, myrcella).
mother(cersei, joffrey).
```

```
?-father(X, tommen)
X=Jamie
```

```
?-father(jamie, Y)
Y=tommen
Y=myrcella
Y=joffrey
```

```
?-father(X, Y)
X=jamie, Y=tommen
X=jamie, Y=myrcella
X=jamie, Y=joffrey
```

# We could go further and define some sibling facts

```
sibling(tommen, myrcella).
sibling(tommen, joffrey).
sibling(joffrey, myrcella).
```

Neither elegant nor scalable.

$$R = (\frac{n^2}{2}) - n$$

There has to be a better way...

# Rules

Specify relationships between facts

*$X$ and $Y$ are siblings if $X$ and $Y$*

*share a mother or a father*

```
sibling(X, Y) :-
    mother(Z, X),
    mother(Z, Y),
    X \== Y.

sibling(X, Y) :-
    father(Z, X),
    father(Z, Y),
    X \== Y.
```

```
?- sibling(X, Y).
X = tommen, Y = myrcella
X = tommen, Y = joffrey
X = myrcella, Y = tommen
```

# More relations...

```
uncle_or_aunt(X, Y) :-
    mother(M, Y),
    sibling(M, X).

uncle_or_aunt(X, Y) :-
    father(M, Y),
    sibling(X, M).
```

```
father(tywin, jamie).
father(tywin, cersei).
father(tywin, tyrion).
```

```
?- uncle_or_aunt(X ,Y).
X = jamie, Y = tommen
X = tyrion, Y = tommen
X = jamie, Y = myrcella
X = tyrion, Y = myrcella
X = jamie, Y = joffrey
X = tyrion, Y = joffrey
X = cersei, Y = tommen
X = tyrion, Y = tommen
X = cersei, Y = myrcella
X = tyrion, Y = myrcella
X = cersei, Y = joffrey
X = tyrion, Y = joffrey
```

# Lists and some operations

```
[1, 2, 3]
[one, two , three]
```

# Referencing items in lists

```
[ F | R ]
```

*The first part of the list, and the rest of the list*

```
[a, b, c]
```

Then `[ F | R ]` equates to

`F=a, R=[b, c]`

# The append clause

Prolog has a useful clause for appending to a list.

```
append(A, B, C)
```

```
?-append([1], [2, 3], C)
C=[1, 2, 3]
```

append is nothing more than a clause

*Succeeds if C is the result of appending B to A*

Prolog is working out the value(s) for C which make the append() clause **True**

But, because this is prolog,

we can do this

```
?-append([1], B, [1, 2, 3]).
B=[2,3]
```

# and this

```
?-append(A, B, [1, 2, 3]).
A = [],         B = [1, 2, 3]
A = [1],        B = [2, 3]
A = [1, 2],     B = [3]
A = [1, 2, 3], B = []
```

# The "Don't care" variable

_

*Used like a variable but it tells prolog we **don't care** what it's value is.*

`[a, b, c]`

Then `[F | _]` equates to

`F = a`, we **don't care** about the rest

# Solving Einstein's Riddle

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# Who owns the zebra and who drinks water?

For each house there are 5 factors to consider

- The nationality of the **Owner**
- The **Pet**
- The **Cigaret** brand
- The **Drink**
- The **Color**

# A **fact** for houses

```
house(Owner, Pet, Cigarette, Drink, Color)
```

# The houses rule

Succeeds when $H$ is a list of 5 **facts** which, collectively, satisfy requirements 2 - 15

```
houses(H) :-
    % There are 5 houses,
    % The Englishman lives in the red house,
    % The Spaniard owns the dog,
```

We can start building up facts about the houses piece by piece

We'll use the **don't care** variable where information is not provided

*there are 5 houses*

```
houses(H) :-
    length(H, 5),
    ...
```

Succeeds if $|H| = 5$

*The **Englishman** lives in the **red** house.*

```
houses(H) :-
    ...
    member(house(englishman,_,_,_,red), H),
    ...
```

*The **Spaniard** owns the **dog**.*

```
houses(H) :-
    ...
    member(house(spaniard,dog,_,_,_), H),
    ...
```

***Coffee** is drunk in the **green** house.*

```
houses(H) :-
    ...
    member(house(_,_,_,coffee,green), H),
    ...
```

## *The **Ukrainian** drinks **tea***

```
houses(H) :-
    ...
    member(house(ukrainian,_,_,tea,_), H),
    ...
```

*The **green** house is immediately to the right of the **ivory** house.*

We need a **rule** to determine which houses are next to one another

# The `next(A, B)` clause

Houses $A$ and $B$ are next to each other if

$A$ is next to $B$

```
next(A, B, L) :-

append(_, [A,B|_], L).
```

Or if $B$ is next to $A$

```
next(A, B, L) :-

append(_, [B,A|_], L).
```

*The **green** house is immediately to the right of the **ivory** house.*

```
houses(H) :-
    ...
    next(house(_,_,_,_,ivory),house(_,_,_,_,green), H),
    ...
```

*The **Old Gold** smoker owns **snails**.*

```
houses(H) :-
    ...
    member(house(_,snails,gold,_,_), H),
    ...
```

***Kools** are smoked in the **yellow** house.*

```
houses(H) :-
    ...
    member(house(_,_,kools,_,yellow), H),
    ...
```

***Milk** is drunk in the **middle house**.*

```
houses(H) :-
    ...
    H = [_,_,house(_,_,_,milk,_),_,_],
    ...
```

*The **Norwegian** lives in the **first house**.*

```
houses(H) :-
    ...

    H = [house(norwegian,_,_,_,_)|_],
    ...
```

*The man who smokes **Chesterfields** lives in the house next to the man with the **fox**.*

```
houses(H) :-
    ...

    next(house(_,fox,_,_,_), house(_,_,chesterfield,_,_), H),
    ...
```

*__Kools__ are smoked in the house next to the house where the __horse__ is kept.*

```
houses(H) :-
    ...

    next(house(_,_,kools,_,_), house(_,horse,_,_,_), H),
    ...
```

*The **Lucky Strike** smoker drinks*

***orange juice**.*

```
houses(H) :-
    ...

    member(house(_,_,lucky,juice,_), H),
    ...
```

*The **Japanese** smokes **Parliaments.***

```
houses(H) :-
    ...
    member(house(japanese,_,parliaments,_,_), H),
    ...
```

*The **norwegian** lives next to the **blue** house*

```
houses(H) :-
    ...
    next(house(norwegian,_,_,_,_), house(_,_,_,_,blue), H).
    ...
```

# The Zebra Owner Rule

Succeeds when some list $H$ meets all of the 15 criteria and, contains a house with a zebra.

```
zebra_owner(O) :-
    houses(H),
    member(house(O,zebra,_,_,_), H).
```

No facts explicitly match **Zebra**

But this rule will also match any facts with no pet value.

There was only one

```
?-zebra_owner(0).
0=japanese
```

*The **Japanese** man owns the **Zebra***

# The Water Drinker rule

Succeeds when some list $H$ meets all of the 15 criteria and, contains a house where water is drunk.

```
water_drinker(D) :-
    houses(H),
    member(house(D,_,_,water,_), H).
```

Like the Zebra rule, this rule will match any facts with no **Drink** value.

# There was only one

```
?-water_drinker(D).
D=norwegian
```

*The **Norwegian** man drinks the **Water***

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# Resources

- 4 Programming Paradigms in 40 minutes
  https://youtu.be/cgVVZMfLjEI?t=1185
- The Birth of Prolog
  http://web.archive.org/web/20070703003934/www.l
  mrs.fr/~colmer/ArchivesPublications/HistoireProlog/1

- https://en.wikibooks.org/wiki/Prolog
- http://www.cs.trincoll.edu/~ram/cpsc352/notes/prolo
- http://infolab.stanford.edu/~ullman/focs/ch12.pdf

# Online Compilers

- https://swish.swi-prolog.org/
- https://www.tutorialspoint.com/execute_prolog_online