Prolog: Programming in Logic

The original declarative programming language

- Courses in programming languages …
  - Prolog is always the declarative language they teach.
  - (imperative, functional, object-oriented, declarative)

- Alain Colmeraeur & Philippe Roussel, 1971-1973
  - With help from theorem proving folks such as Robert Kowalski
  - Original project: Type in French statements & questions
    - Computer needed NLP and deductive reasoning
  - Efficiency by David Warren, 1977 (compiler, virtual machine)
  - Colmerauer & Roussel wrote 20 years later:
    "Prolog is so simple that one has the sense that sooner or later someone had to discover it … that period of our lives remains one of the happiest in our memories.
  - "We have had the pleasure of recalling it for this paper over almonds accompanied by a dry martini."

Constants vs. Variables

- Variables start with A,B,…Z or underscore:
  - Food, Person, Person2, _G123
- Constant "atoms" start with a,b,…z or appear in single quotes:
  - josie, curry, 'CS325'
  - Other kinds of constants besides atoms:
    - Integers -7, real numbers 3.14159, the empty list []
    - eats(josie,curry) is technically a constant **structure**

- Nothing stops you from putting constants into constraints:
  - eats(josie, Food). % what Food does Josie eat? (2 answers)
  - eats(Person, curry). % what Person eats curry? (2 answers)
  - eats(josie, Food), eats(Person, Food). % who'll share what with Josie?
    - Food=curry, Person=sam

How does matching happen?

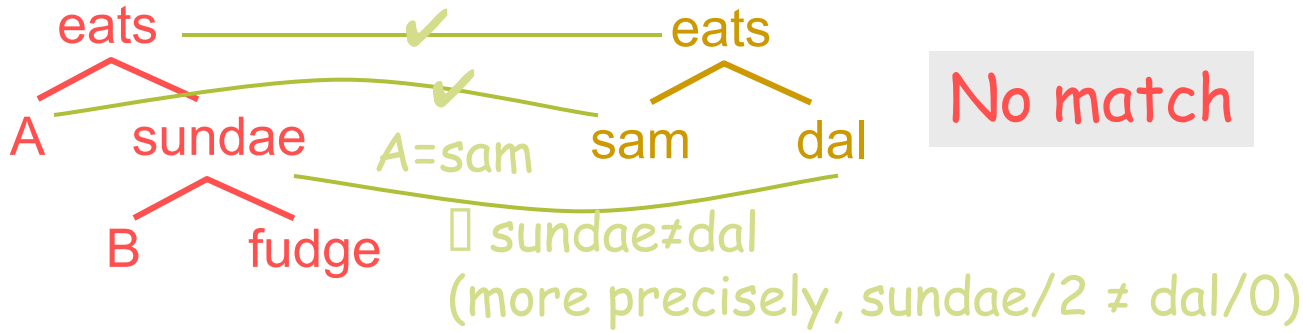
- eats(sam, dal).
- eats(josie, sundae(vanilla, caramel)).
- eats(rajiv, sundae(mintchip, fudge)).
- eats(robot('C-3PO'), Anything). % variable in a fact

- Query: eats(A, sundae(B,fudge)).
- Answer: A=rajiv, B=mintchip

How does matching happen?

- **eats(sam, dal).**
- eats(josie, sundae(vanilla, caramel)).
- eats(rajiv, sundae(mintchip, fudge)).
- eats(robot('C-3PO'), Anything). % variable in a fact

- Query: eats(A, sundae(B,fudge)).
- What happens when we try to match this against facts?



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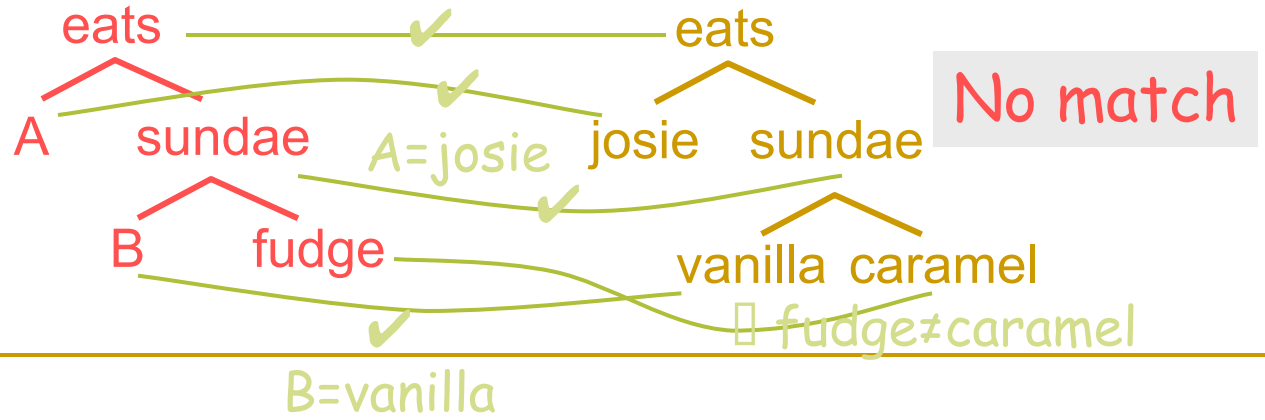

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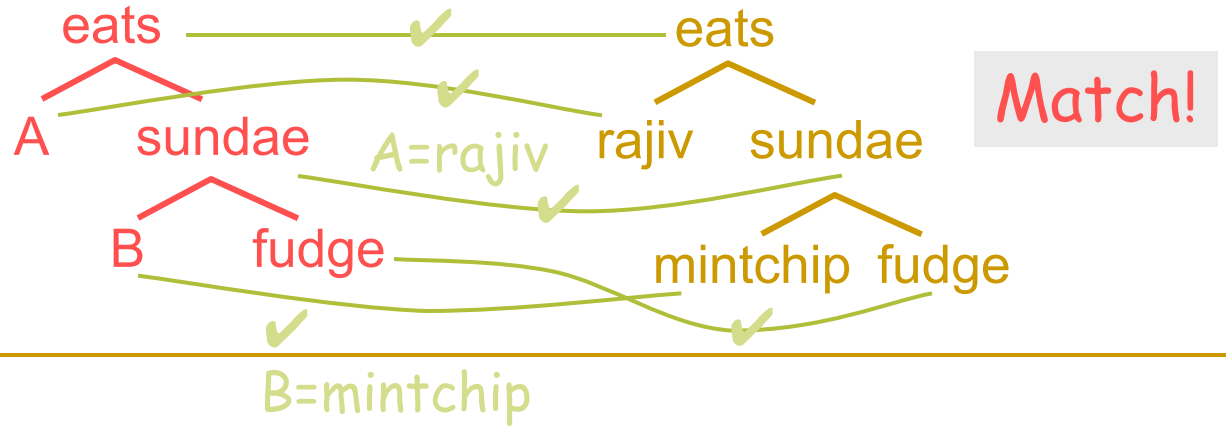
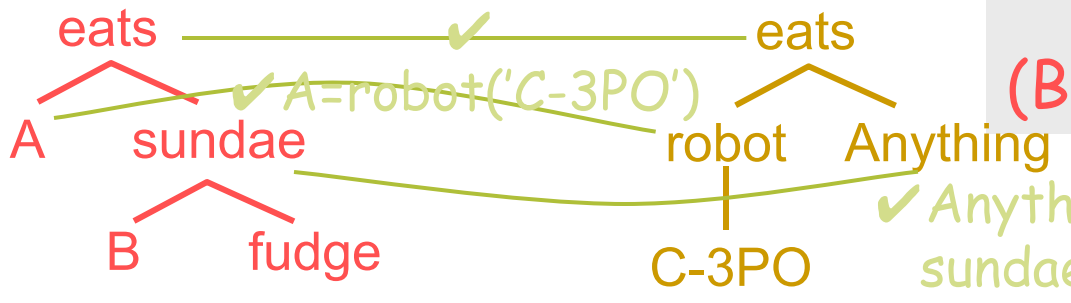
- Query: eats(A, sundae(B,fudge)).
- What happens when we try to match this against facts?



How does matching happen?

- eats(sam, dal).
- eats(josie, sundae(vanilla, caramel)).
- eats(rajiv, sundae(mintchip, fudge)).
- **eats(robot('C-3PO'), Anything).** % variable in a fact

- Query: eats(A, sundae(B,fudge)), icecream(B).
- What happens when we try to match this against facts?



Match!
(B still unknown)

How does matching happen?

- eats(sam, dal).
- eats(josie, sundae(vanilla, caramel)).
- eats(rajiv, sundae(mintchip, fudge)).
- **eats(robot('C-3PO'), Something) :- food(Something).**
- food(dal). icecream(vanilla).
- food(fudge). icecream(chocolate).
- **food(sundae(Base, Topping)) :- icecream(Base), food(Topping).**

- Query: eats(robot(A), sundae(B,fudge)).
- Answer: A='C-3PO', B can be any kind of ice cream

Family trees (just Datalog here) …

```
female(sarah).
female(rebekah).
female(hagar_concubine).
female(milcah).
female(bashemath).
female(mahalath).
female(first_daughter).
female(second_daughter).
female(terahs_first_wife).
female(terahs_second_wife).
female(harans_wife).
female(lots_first_wife).
female(ismaels_wife).
female(leah).
female(kemuels_wife).
female(rachel).
female(labans_wife).
```

```
male(terah).  male(abraham).
male(nahor). male(haran).
male(isaac).  male(ismael). male(uz).
      male(kemuel). male(bethuel).
male(lot). male(iscah).
male(esau). male(jacob).
male(massa). male(hadad).
male(laban). male(reuel).
male(levi3rd). male(judah4th).
male(aliah). male(elak).
male(moab). male(ben-ammi).
```

Family trees (just Datalog here) …

```
father(terah, sarah).
father(terah, abraham).
father(terah, nahor).
father(terah, haran).
father(abraham, isaac).
father(abraham, ismael).
father(nahor, uz).
father(nahor, kemuel).
father(nahor, bethuel).
father(haran, milcah).
father(haran, lot).
father(haran, iscah).
father(isaac, esau).
father(isaac, jacob).
father(ismael, massa).
father(ismael, mahalath).
father(ismael, hadad).
father(ismael, bashemath).
father(esau, reuel).
father(jacob, levi3rd).
father(jacob, judah4th).
father(esau, aliah).
father(esau, elak).
father(kemuel, aram).
father(bethuel, laban).
father(bethuel, rebekah).
father(lot, first_daughter).
father(lot, second_daughter).
father(lot, moab).
father(lot, ben_ammi).
father(laban, rachel).
father(laban, leah).
```

```
mother(terahs_second_wife, sarah).
mother(terahs_first_wife, abraham).
mother(terahs_first_wife, nahor).
mother(terahs_first_wife, haran).
mother(sarah, isaac).
mother(hagar_concubine, ismael).
mother(milcah, uz).
mother(milcah, kemuel).
mother(milcah, bethuel).
mother(harans_wife, milcha).
mother(harans_wife, lot).
mother(harans_wife, iscah).
mother(rebekah, esau).
mother(rebekah, jacob).
mother(ismaels_wife, massa).
mother(ismaels_wife, mahalath).
mother(ismaels_wife, hadad).
mother(ismaels_wife, bashemath).
mother(bethuels_wife, laban).
mother(bethuels_wife, rebekah).
mother(lots_first_wife, first_daughter).
mother(lots_first_wife, second_daughter).
mother(first_daughter, moab).
mother(second_daughter, ben_ammi).
mother(bashemath, reuel).
mother(leah, levi3rd).
mother(leah, judas4th).
mother(mahalath, aliah).
mother(mahalath, elak).
mother(lebans_wife, rachel).
mother(lebans_wife, leah).
```

Family trees (just Datalog here) …

- husband(terah, terahs_first_wife).
  husband(terah, terahs_second_wife).
  husband(abraham, sarah).
  husband(abraham, hagar_concubine).
  husband(nahor, milcah).
  husband(haran, harans_wife).
  husband(isaac, rebekah).
  husband(ismael, ismaels_wife).
  husband(kemuel, kemuels_wife).
  husband(bethuel, bethuels_wife).
  husband(lot, lots_first_wife).
  husband(lot, first_daughter).
  husband(lot, second_daughter).
  husband(esau, bashemath).
  husband(jacob, leah).
  husband(jacob, rachel).
  husband(esau, mahalath).
  husband(laban, labans_wife).

- wife(X, Y):- husband(Y, X).
- married(X, Y):- wife(X, Y).
- married(X, Y):- husband(X, Y).

convention in these slides

Does husband(X,Y) mean
"X is the husband of Y"
or
"The husband of X is Y"?

Conventions vary … pick one and stick to it!

Tower of Honoi

```
move(1,X,Y,_) :-
    write('Move top disk from '),
    write(X),
    write(' to '),
    write(Y),
    nl.
move(N,X,Y,Z) :-
    N>1,
    M is N-1,
    move(M,X,Z,Y),
    move(1,X,Y,_),
    move(M,Z,Y,X).

?- move(3,left,right,center).
```

move(3,left,right,center) if
    move(2,left,center,right) and] *
    move(1,left,right,center) and
    move(2,center,right,left).] **

In order to satisfy the goal ?- move(3,left,right,center) do this :
satisfy the goal ?-move(2,left,center,right), and then
satisfy the goal ?-move(1,left,right,center), and then
satisfy the goal ?-move(2,center,right,left).

Also, we could write the declarative readings for N=2:
move(2,left,center,right) if] *
    move(1,left,right,center) and
    move(1,left,center,right) and
    move(1,right,center,left).

move(2,center,right,left) if] **
    move(1,center,left,right) and
    move(1,center,right,left) and
    move(1,left,right,center).