Introduction to Prolog

Properties of Prolog as a Programming language:

- no explicit types or classes
- rule-based, founded on first-order logic
- high expressibility: functionality per program line
- interactive, experimental programming

NB: A few examples in these ppt slides differ from note, sorry 'bout that, but I had some nice animations prepared... :)

Background for Prolog

***PRO**gramming in **LOG**ic*

Syntax: subset of 1.-order logic

Declarative semantics: Logical consequence

Procedural semantics:

Resolution, proof rule with unification; Robinson, 1965

A.Colmerauer & co. (Marseille), ca. 1970: "Prolog"

D.H.D. Warren: Efficient compiler, abstract machine "WAM", 1975, ...

Language made known by R.Kowalski "Logic for Problem solving", 1979, ...

Prolog and AI

- First major AI language was LISP, McCarthy & al., 1960
  - symbolic computation
  - programs ≈ data
- Prolog, intended for computational linguistics, has become a successor of LISP for AI applications
- A Prolog program is representation of knowledge ≈ a database (relational DB + a lot more)
- Prolog applies backward-chaining (cf. MN, chap 2).
- Prolog includes strong metaprogramming facilities (programs ≈ data; easy to defining interpreters)

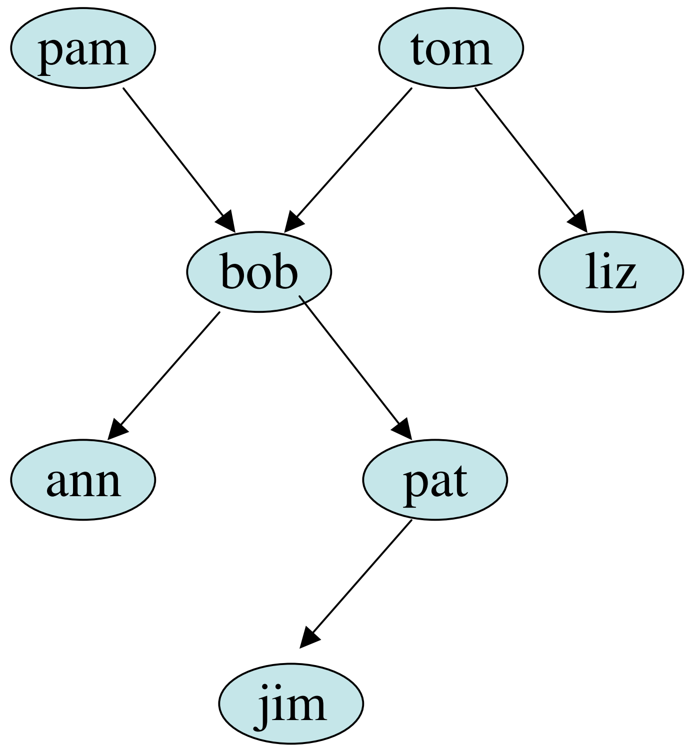
Later in the course, extensions to Prolog

- Constraint Handling Rules
- allows to mix forward and backward chaining...
- Abductive logic programming

But now, let's jump into basic Prolog

Program is a *description* of data

```
parent( pam, bob). % Pam is a parent of Bob
parent( tom, bob).
parent( tom, liz).
parent( bob, ann).
parent( bob, pat).
parent( pat, jim).
```



Basic notions:

- predicates: **`parent`**
  - describes a relation
  - defined by facts, rules, collectively called clauses
- constant (symbol)s: **`tom`**, **`bob`**, **`x`**, **`y`**
- variables: **`X`**, **`Y`**, **`Tom`**
- atoms (simple goals): **`parent(A,a)`**
- Queries....

In Prolog literature, constants are called atoms :(

Queries

Atomic queries

`?- parent(X,Y).`

... give me values of **`X`** and **`Y`** so **`parent(X,Y)`** logically follows from program

Compound query

`?- parent(pam, X), parent(X, Y).`

... give me **`X`** and **`Y`**, so that...

Procedural semantics

```
parent( pam, bob).
parent( tom, bob).
parent( tom, liz).
parent( bob, ann).
parent( bob, pat).
parent( pat, jim).
```

```
?- parent(pam, X), parent(X, Y).
?- parent(bob, Y).
```

X=bob

Y=ann

Y=pat

- Unification term=term?
- from left to right
- from start to end
- backtracking
  ≈ undo and try new choices

Success!
Other Solutions?

No more possible
solutions here :(

Rules

```
female(pam).
male(tom).
male(bob).
female(liz).
female(pat).
female(ann).
male(jim).

mother(X, Y):-
      parent(X, Y),
      female(X).
```

Procedural semantics

as before + rewrite subgoal using rules

Declarative semantics ≈ logical consequence

with rules read as, e.g.

$\forall$x,y,x: p(x,y) $\wedge$ f(x) $\rightarrow$ m(x,y)

The nice property:

procedural ≈ declarative

(unless procedural semantics loops)

A recursive rule

```
ancestor(X, Z):-
    parent(X, Z).

ancestor(X, Z):-
    parent(X, Y),
    ancestor(Y, Z).
```

```
?- ancestor(tom, pat).
```

Works fine but may loop if ordering of things changed

Range-restricted programs (RR)

≈ those that can be understood as databases

≈ guaranteed finite relations

Counter examples:

```
equal(X,X).
big_number(X):- X>4.
```

Predefined predicate

Example:

```
elder_sister(X,Y):-
    girl(X,AgeX), girl(Y,AgeY),
    X \== Y,
    parent(Z,X), parent(Z,Y),
    AgeX > AgeY.
```

Definition:

A clause is RR if any variable in its head occurs in its body and any variable in a predefined test occurs also in an atom with program-defined predicate in that body [to the left of it].

A program is RR if all its clauses are RR.

Negation-as-failure

Closed-world assumption: Anything not known by database considered false.

Implicit quantifiers:

∃Z Z ∃Z Z

Example:

```
orphan(X):- person(X), \+ father(_,X), \+ mother(_,X).
person(adam).
person(abel).
father(adam,abel).
```

Extend definition of range restriction:

... and any variable in negated atom not covered by ∃, must occurs also in an atom with program-defined predicate [to the left of it].

Counter example:

Problems with Prolog's approximation to NaF

```
p(a).
```

Test negation

```
?- \+ p(a).
no
?- \+ p(b).
yes
```

Looks fine but sem'cs problematic in case of variables:

```
?- X = b, \+ p(X).
X = b ?
yes
?- \+ p(X), X = b.
no
```

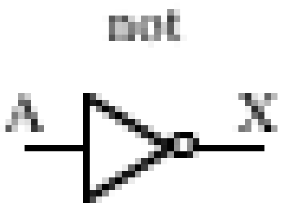
Consider

- How many lines of Java code is needed for implementing the little family database?
- Another example suited to illustrate
  - Prolog's semantics
  - "Simple, yet powerful"

Logical circuits

(Abstraction over) simple, electrical circuits

often app. 0V ≈ 0, app. 5V ≈ 1



A	X
0	1
1	0

In Prolog:

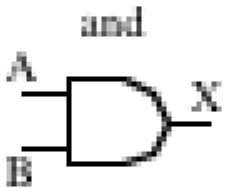
```
not(0,1).
not(1,0).
```

More simple gates

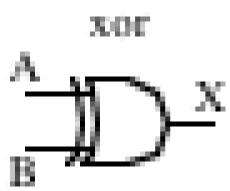
```
and(0, 0, 0).
and(0, 1, 0).
and(1, 0, 0).
and(1, 1, 1).

xor(0, 0, 0).
xor(0, 1, 1).
xor(1, 0, 1).
xor(1, 1, 0).

or(0, 0, 0).
or(0, 1, 1).
or(1, 0, 1).
or(1, 1, 1).
```



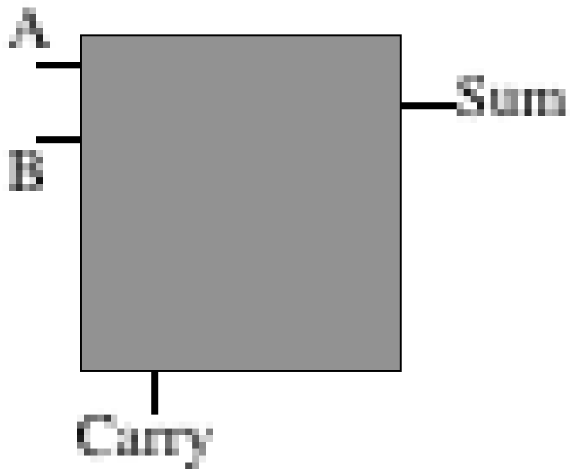
A	B	X
0	0	0
0	1	0
1	0	0
1	1	1



A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

Building circuits from gates

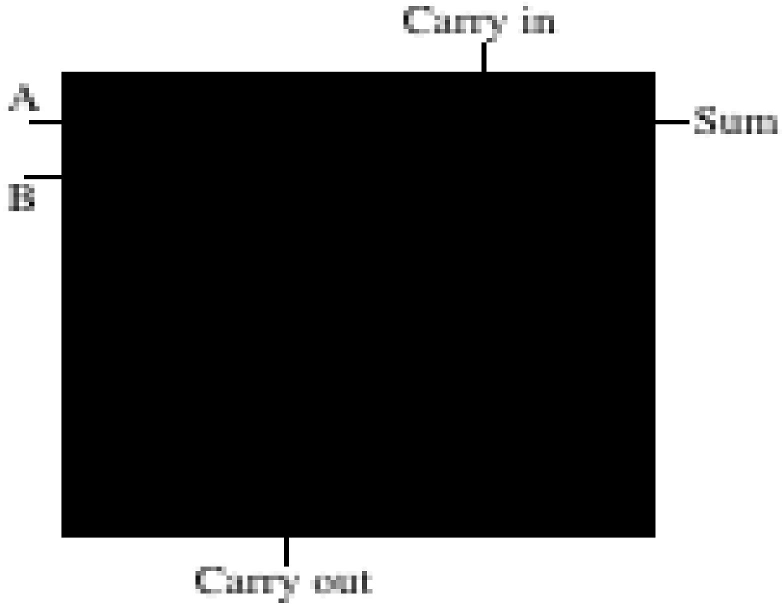
Example: A half-adder
Adding two bits, A and B:




```
halfadder(A, B, Carry, Sum):-
```

Notice: Analogy between Prolog variable and electrical conductor

A full-adder, now with old carry




```
fulladder(A, B, Carryin, Sum, Carryout):-
```

[redacted]

Predicates in Prolog (often) reversible

What do we get of output when inputting 0,1,1?

```
?- fulladder(0,1,1,S,C).
C = 1, S = 0 ?
```

What input gives output = 0, 1?

```
?- fulladder(X,Y,Z,0,1).
X = 0, Y = 1, Z = 1 ? ;
X = 1, Y = 0, Z = 1 ? ;
X = 1, Y = 1, Z = 0 ? ;
no
```

Reversible: no distinction between
input- og output-variable!
Another word for reversible: Relationel