University of Auckland

07.363

Functional and Logic Programming

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Executing Prolog

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Matching I

The rule:

```
deriv(U ^C, X, C * U ^L * DU) :-
     number(C), L is C - 1,
     deriv(U, X, DU).

?- deriv(x ^3, x, D).
   D = 1*3*x^2
```

The goal:

- `x ^3` matches `U ^C`
  - $x = U, C = 3$
- `x` matches `X`
- `D` matches `C * U ^L * DU`

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Matching II

```
deriv(U+V, X, DU + DV) :-
   deriv(U, X, DU),
   deriv(V, X, DV).

?- deriv(x^3 + x^2 + 1, x, D).
   D = 1*3*x^2+1*2*x^1+0
```

- `x ^3 + x^2 + 1` matches `U + V`
  - `x ^3 + x^2` is bound to `U`
  - `1` is bound to `V`

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Matching III

Can two terms A and F be "made identical," by assigning values to their variables?

Two terms A and F match if

1. they are identical atoms
2. one or both are uninstantiated variables
3. they are terms $A = f_A(a_1, \cdots, a_n)$ and $F = f_F(f_1, \cdots, f_m)$, and
   (a) the arities are the same ($n = m$)
   (b) the functors are the same ($f_A = f_F$)
   (c) the arguments match ($a_i \equiv f_i$)

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Matching – Example I (a)

A	F	$A \equiv F$	variable subst.
a	a	yes	
a	b	no	
sin(X)	sin(a)	yes	$\theta = \{X{=}a\}$
sin(a)	sin(X)	yes	$\theta = \{X{=}a\}$
cos(X)	sin(a)	no	
sin(X)	sin(cos(a))	yes	$\theta = \{X{=}cos(a)\}$

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Matching – Example I (b)

A	F	$A \equiv F$	variable subst.
likes(c, X)	likes(a, X)	no	
likes(c, X)	likes(c, Y)	yes	$\theta = \{X{=}Y\}$
likes(X, X)	likes(c, Y)	yes	$\theta = \{X{=}c,\ X{=}Y\}$
likes(X, X)	likes(c, _)	yes	$\theta = \{X{=}c,\ X{=}\_47\}$
likes(c, a(X))	likes(V, Z)	yes	$\theta = \{V{=}c, Z{=}a(X)\}$
likes(X, a(X))	likes(c, Z)	yes	$\theta = \{X{=}c, Z{=}a(X)\}$

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Matching II

Consequences of Prolog Matching:

- An uninstantiated variable will match any object.
- An integer or atom will match only itself.
- When two uninstantiated variables match, they *share*:
  - When one is instantiated, so is the other (with the same value).
- Backtracking undoes all variable bindings.

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Matching Algorithm

```
FUNC Unify (A, F: term) :  BOOL;
BEGIN
  IF Is_Var(F) THEN
    Instantiate F to A
  ELSIF Is_Var(A) THEN
    Instantiate A to F
  ELSIF Arity(F) ≠ Arity(A) THEN
    RETURN FALSE
  ELSIF Functor(F) ≠ Functor(A) THEN
    RETURN FALSE
  ELSE
    FOR each argument i DO
      IF NOT Unify(A(i), F(i)) THEN
        RETURN FALSE
      ENDIF
    ENDFOR
  ENDIF
  RETURN TRUE;
END
```

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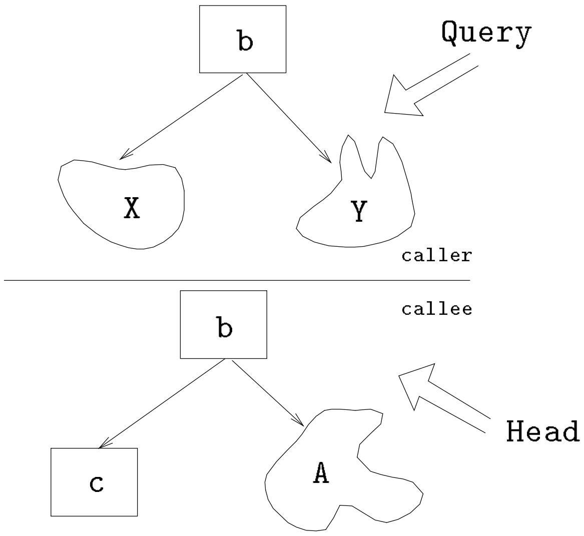
Matching – Example II (a)

p(X, b(X, Y))



p(A, b(c, A)) :- ...

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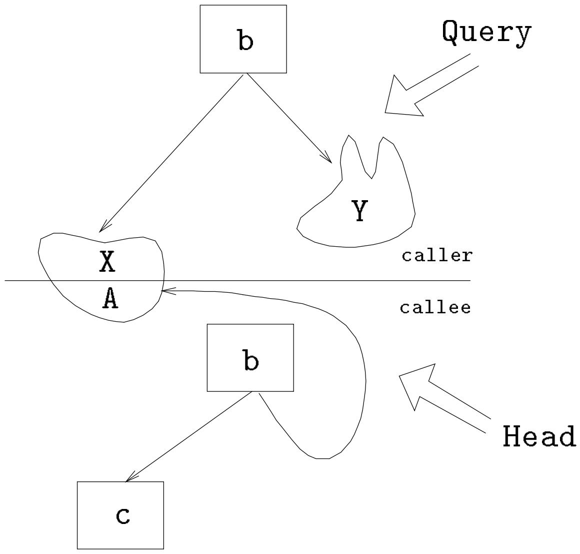
Matching – Example II (b)

p($\boxed{\texttt{X}}$, b(X, Y))



p($\boxed{\texttt{A}}$, b(c, A)) :- ...

$\theta = \{A = X\}$

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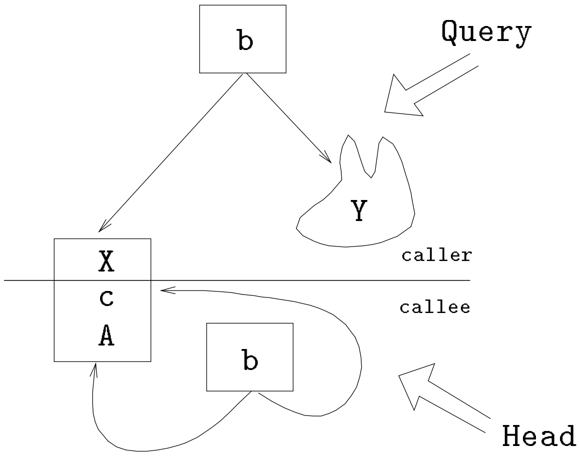
Matching – Example II (c)

p(X, b($\boxed{\texttt{X}}$, Y))



p(A, b($\boxed{\texttt{c}}$, A)) :- ...

$\theta = \{A = X, X = c\}$

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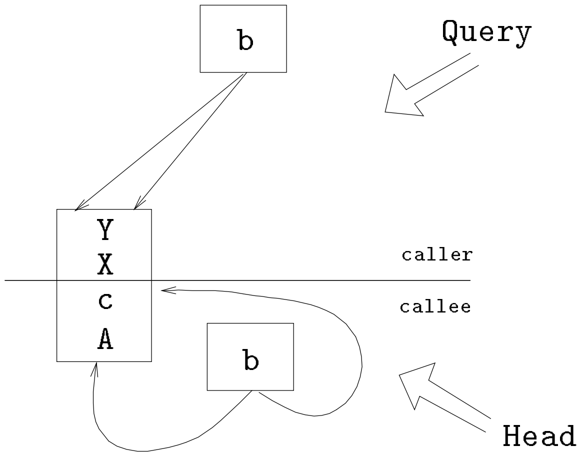
Matching – Example II (d)

p(X, b(X, $\boxed{\texttt{Y}}$))



p(A, b(c, $\boxed{\texttt{A}}$)) :- ...

$\theta = \{A = X, X = c, A = Y\}$

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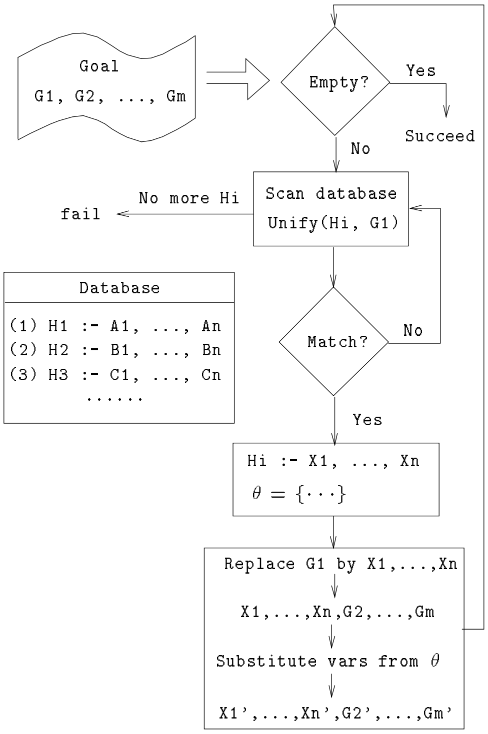
Executing Prolog I



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Executing Prolog II

FUNC `Execute` ($G = G_1, G_2, \cdots, G_m$; `Result`);

IF `Is_Empty`(G) **THEN** `Result := Yes`

ELSE `Result := No`; i `:= 1`;

WHILE `Result=No` & $i \leq$ `NoOfClauses` **DO**

`Clause :=` $\boxed{H_i \text{ :- } B_1, \cdots, B_n}$;

IF `Unify`(G_1, `Clause`, θ) **THEN**

G' `:= substitute`($\boxed{B_1, \cdots, B_n, G_2, \cdots, G_m}$, θ);

`Execute`(G', `Result`);

ENDIF; i `:=` $i + 1$;

ENDDO ENDIF

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Execution Example I

```
% From the Northern Exposure FAQ
% friend(of, kind(name, regular)).
friend(maggie, person(eve, yes)).
friend(maggie, moose(morty, yes)).
friend(maggie, person(harry, no)).
friend(maggie, person(bruce, no)).
friend(maggie, person(glenn, no)).
friend(maggie, person(dave, no)).
friend(maggie, person(rick, no)).
friend(maggie, person(mike, yes)).
friend(maggie, person(joel, yes)).

cause_of_death(morty, copper_deficiency).
cause_of_death(harry, potato_salad).
cause_of_death(bruce, fishing_accident).
cause_of_death(glenn, missile).
cause_of_death(dave, hypothermia).
cause_of_death(rick, hit_by_satellite).
cause_of_death(mike, none_yet).
cause_of_death(joel, none_yet).
```

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Execution Example II

```
alive(X) :- cause_of_death(X, none_yet).

male(morty).  male(harry).  male(bruce).
male(glenn).  male(dave).  male(rick).
male(mike).  male(joel).  female(eve).

pastime(eve, hypochondria).
pastime(mike, hypochondria).
pastime(X, golf) :- job(X,doctor).

job(mike, lawyer).  job(adam, chef).
job(maggie, pilot).  job(joel, doctor).

?- friend(maggie, person(B, yes)),
     male(B),
     alive(B),
     pastime(B, golf).
```

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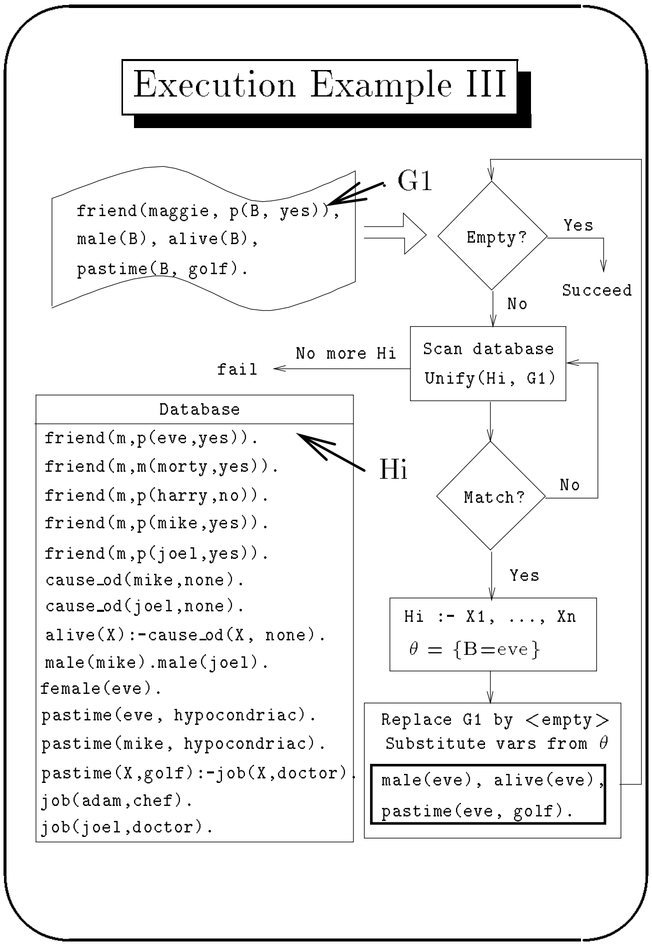

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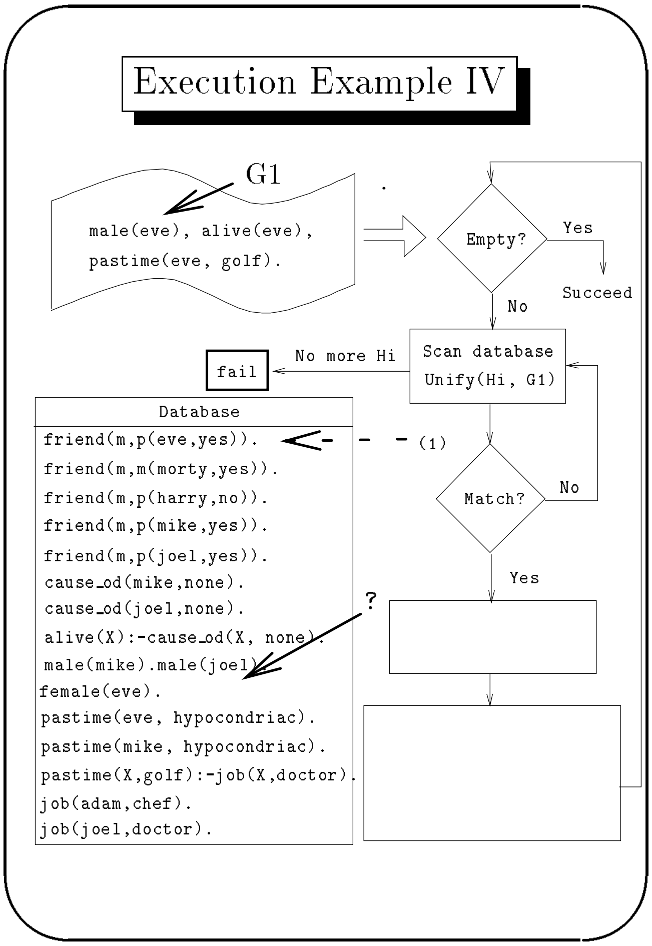

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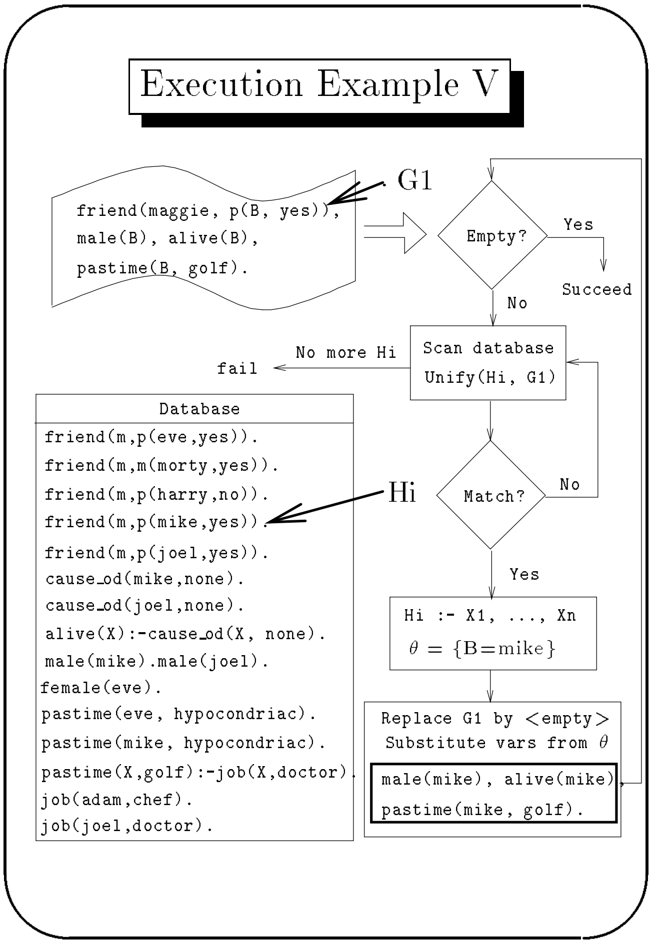

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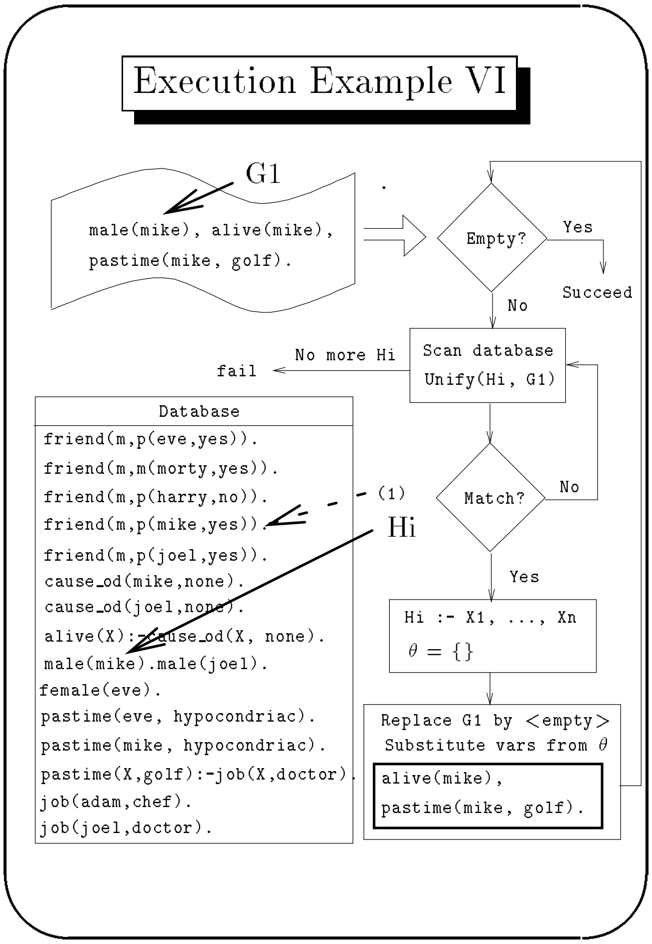

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