CSc 372

Comparative Programming Languages

21 : Prolog — Execution

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Execution

Executing Prolog

- Now that we know about matching, we can take a closer look at how Prolog tries to satisfy goals.
- In general, to solve a goal

$$G = G_1, G_2, \cdots, G_m,$$

  Prolog will first try to solve the sub-goal G_1.
- It solves a sub-goal G_1 it will look for a rule

$$H_i \text{ :- } B_1, \cdots, B_n$$

  in the database, such that G_1 and H_i will match.
- Any variable substitutions resulting from the match will be stored in a variable θ.

Executing Prolog...

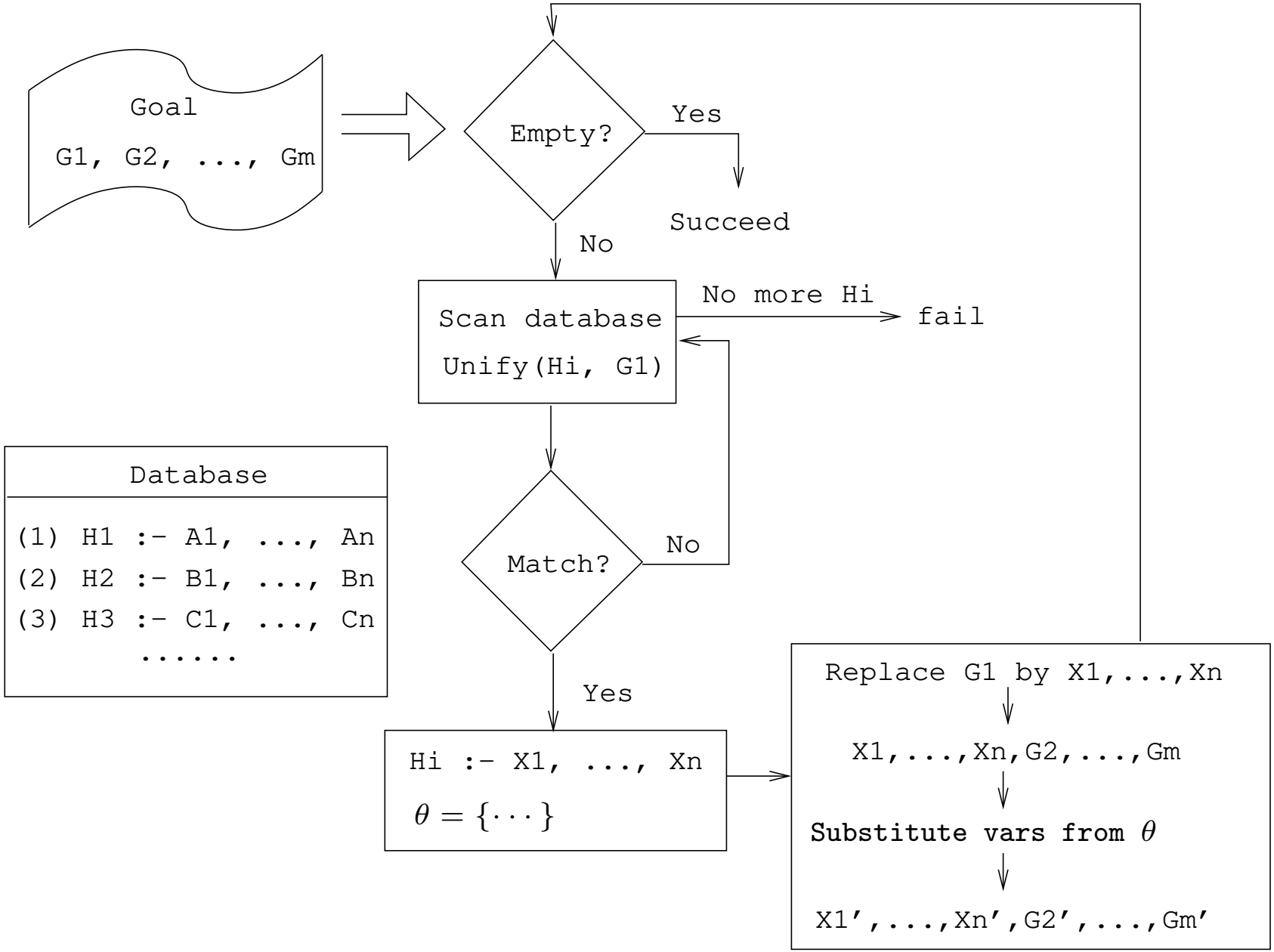
- A new goal will be constructed by replacing G_1 with $B_1, \cdots, B_n$, yielding

$$G' = B_1, \cdots, B_n, G_2, \cdots, G_m.$$

  If $n = 0$ the new goal will be shorter and we'll be one step closer to a solution to G!
- Any new variable bindings from θ are applied to the new goal, yielding G''.
- We recursively try to find a solution to G''.

Executing Prolog...

```
FUNC Execute (G = G_1, G_2, ..., G_m; Result);
    IF Is_Empty(G) THEN Result := Yes
    ELSE
        Result := No;
        i := 1;
        WHILE Result=No & i ≤ NoOfClauses DO
            Clause := H_i :- B_1, ..., B_n;
            IF Unify(G_1, Clause, θ) THEN
                G' := B_1, ..., B_n, G_2, ..., G_m;
                G'' := substitute(G', θ);
                Execute(G'', Result);
            ENDIF;
            i := i + 1;
        ENDDO
    ENDIF
```


Goal
G1, G2, ..., Gm
Empty?
Yes
Succeed
No
Scan database
Unify(Hi, G1)
No more Hi
fail
Database
(1) H1 :- A1, ..., An
(2) H2 :- B1, ..., Bn
(3) H3 :- C1, ..., Cn
.....
Match?
No
Yes
Hi :- X1, ..., Xn
$\theta = \{\cdots\}$
Replace G1 by X1,...,Xn
X1,...,Xn,G2,...,Gm
Substitute vars from θ
X1',...,Xn',G2',...,Gm'

Example

Northern Exposure Example

```
% 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)).
```

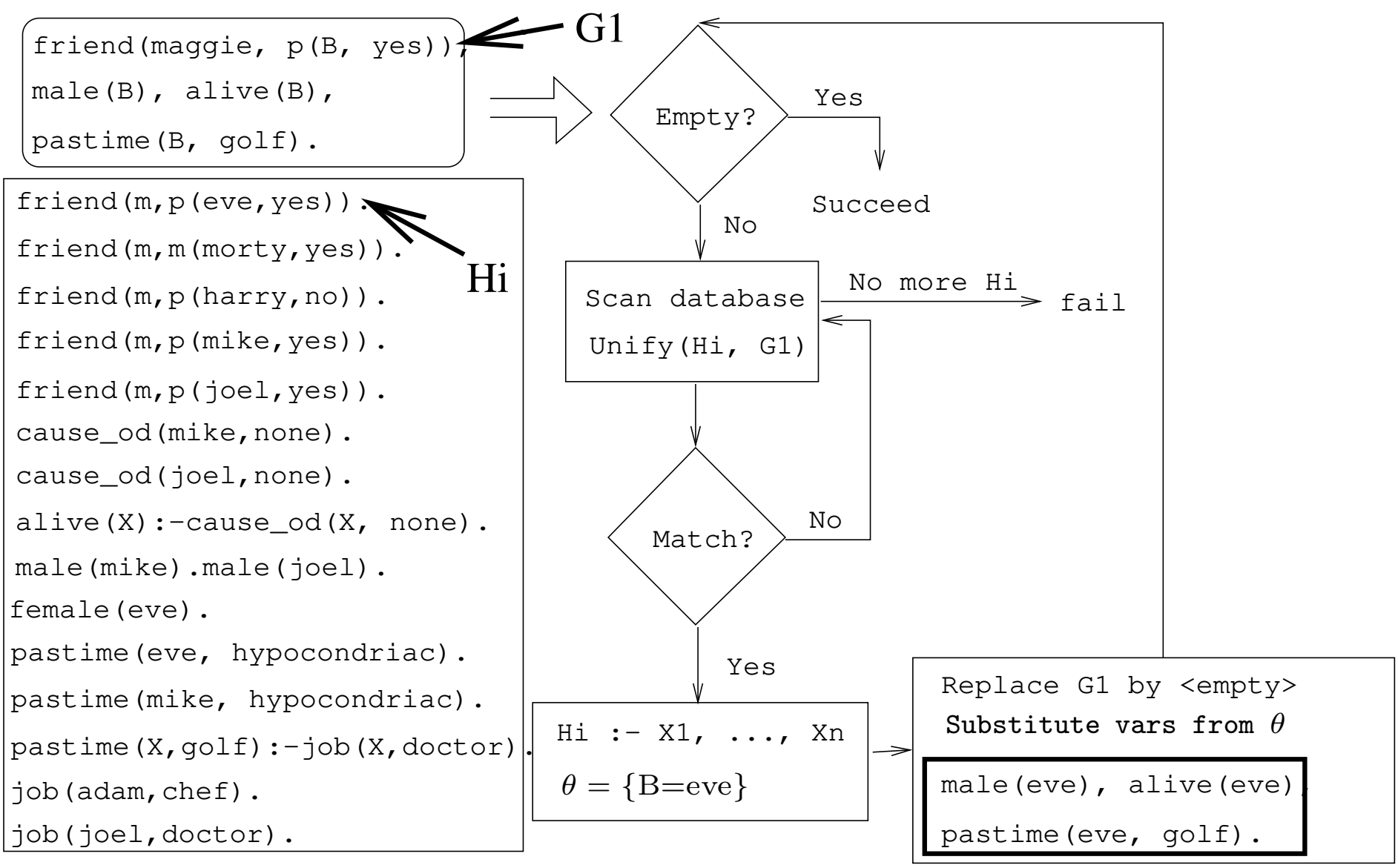
Maggie (Janine Turner)

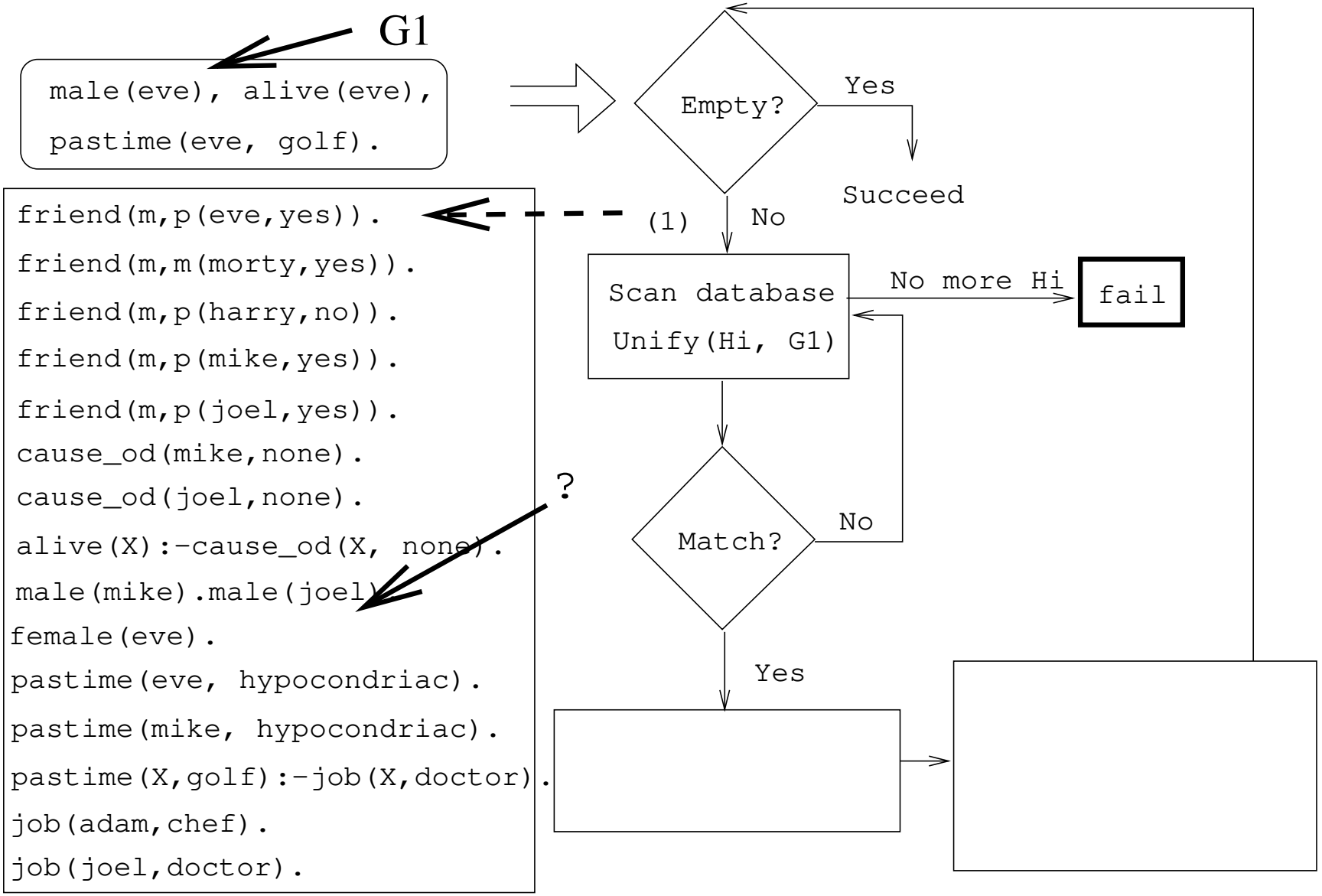
Northern Exposure Example...

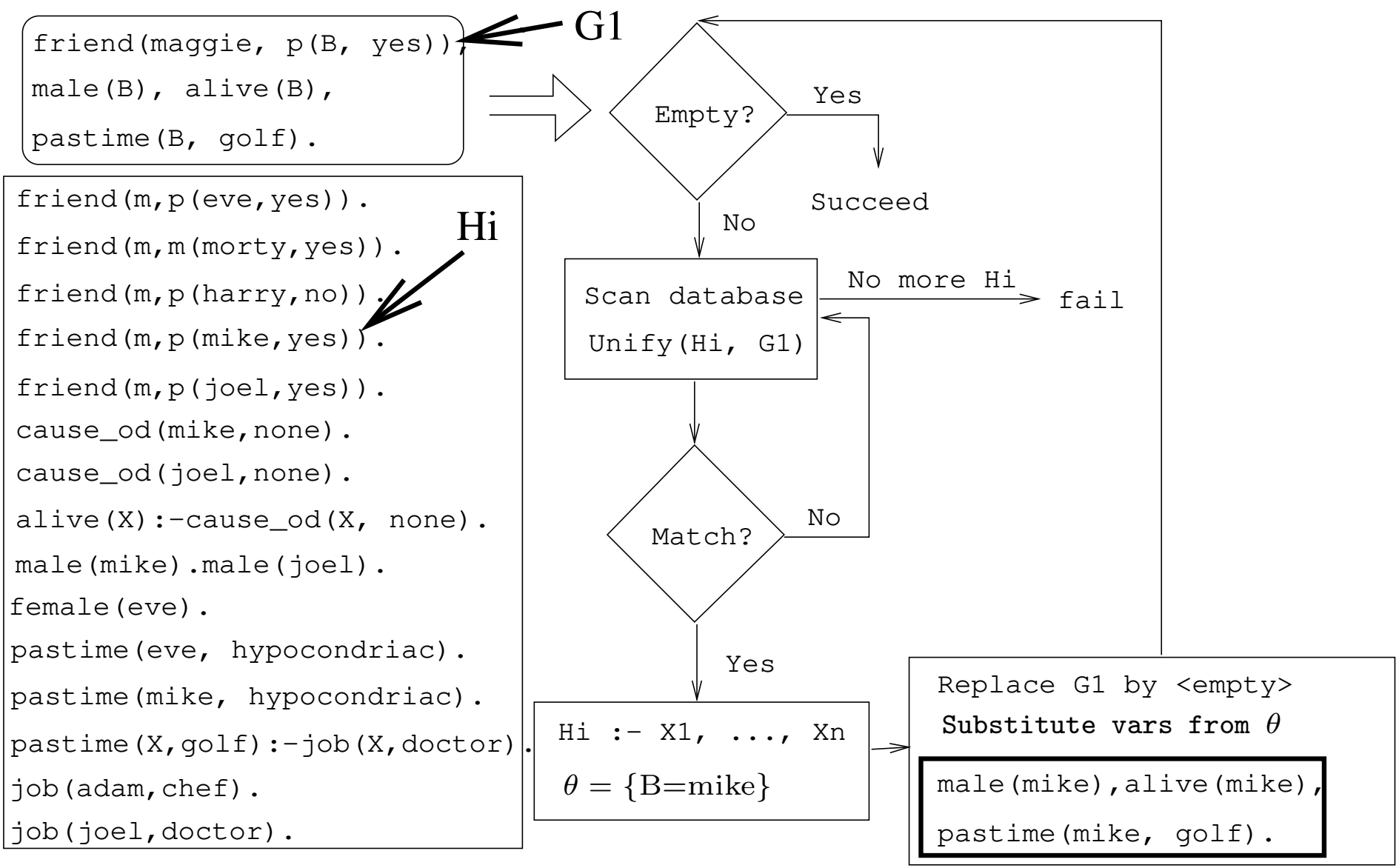
```
cause_of_death(morty, copper_deficiency).
cause_of_death(harry, potato_salad).
cause_of_death(bruce, fishing_accident).
cause_of_death(glenn, missile).
cause_of_death(dave, hypothermia).
cause_of_death(rick, hit_by_satellite).
cause_of_death(mike, none_yet).
cause_of_death(joel, none_yet).

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

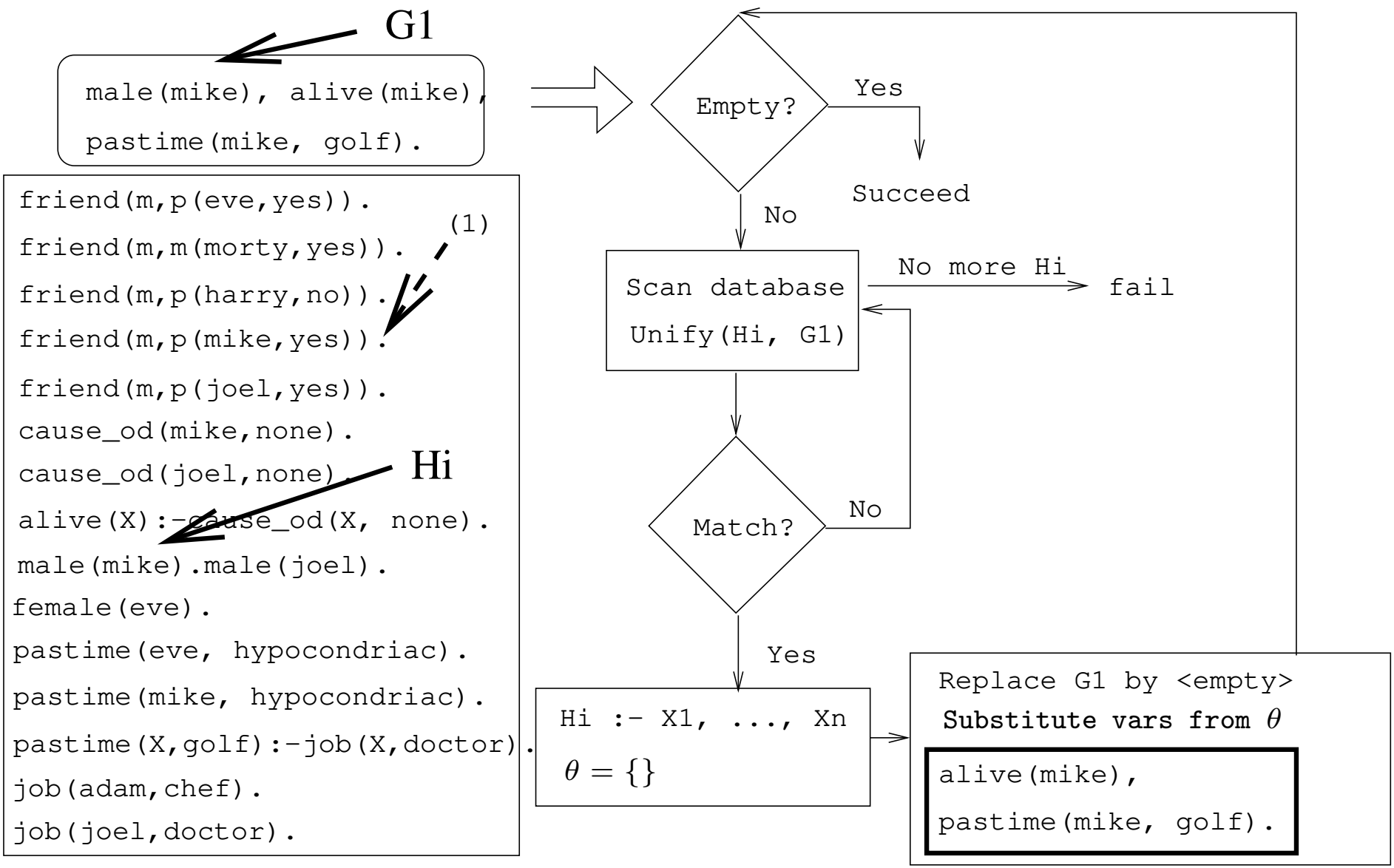
Northern Exposure Example. . .

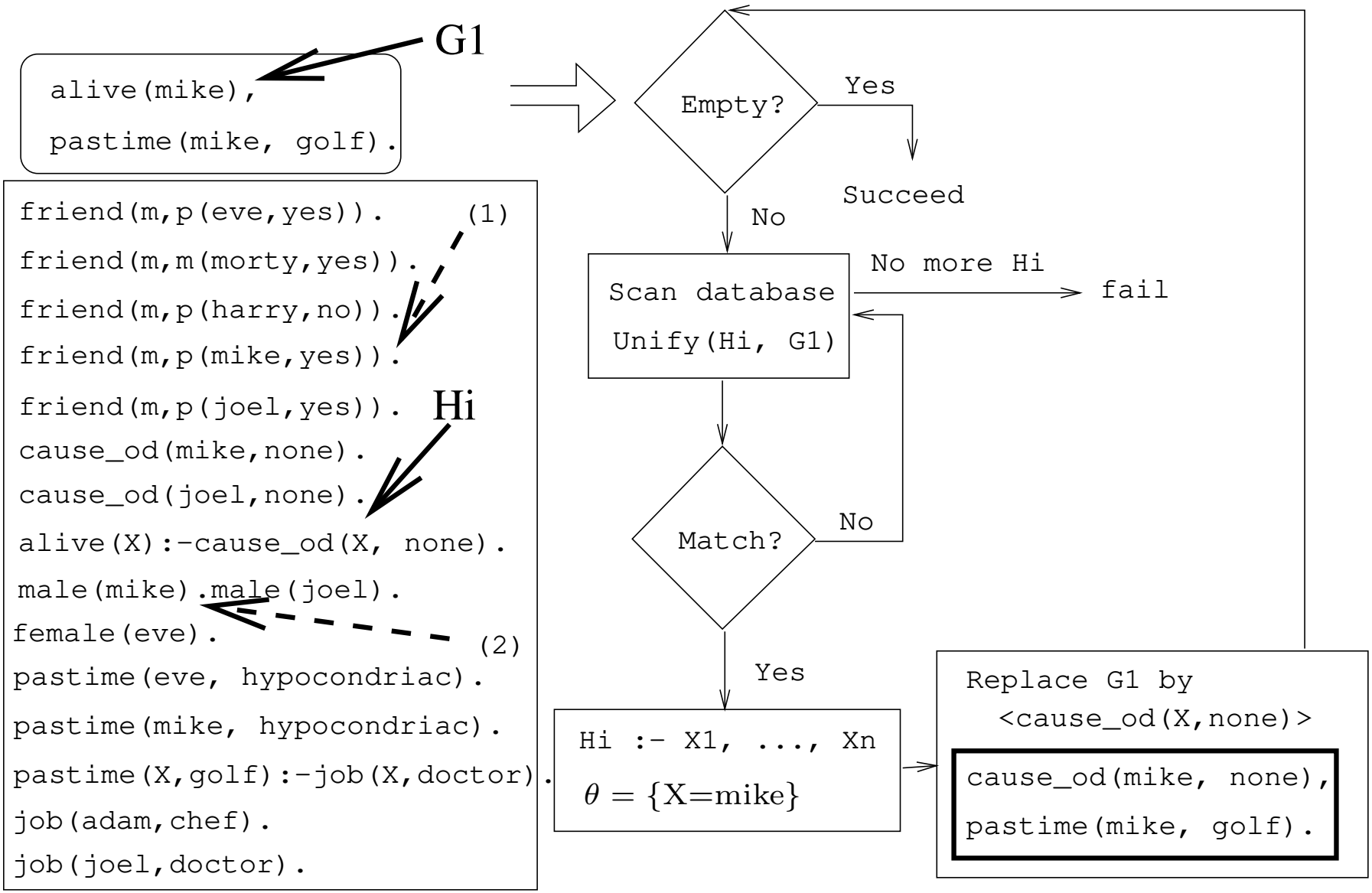
```
alive(X) :- cause_of_death(X, none_yet).

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).
```

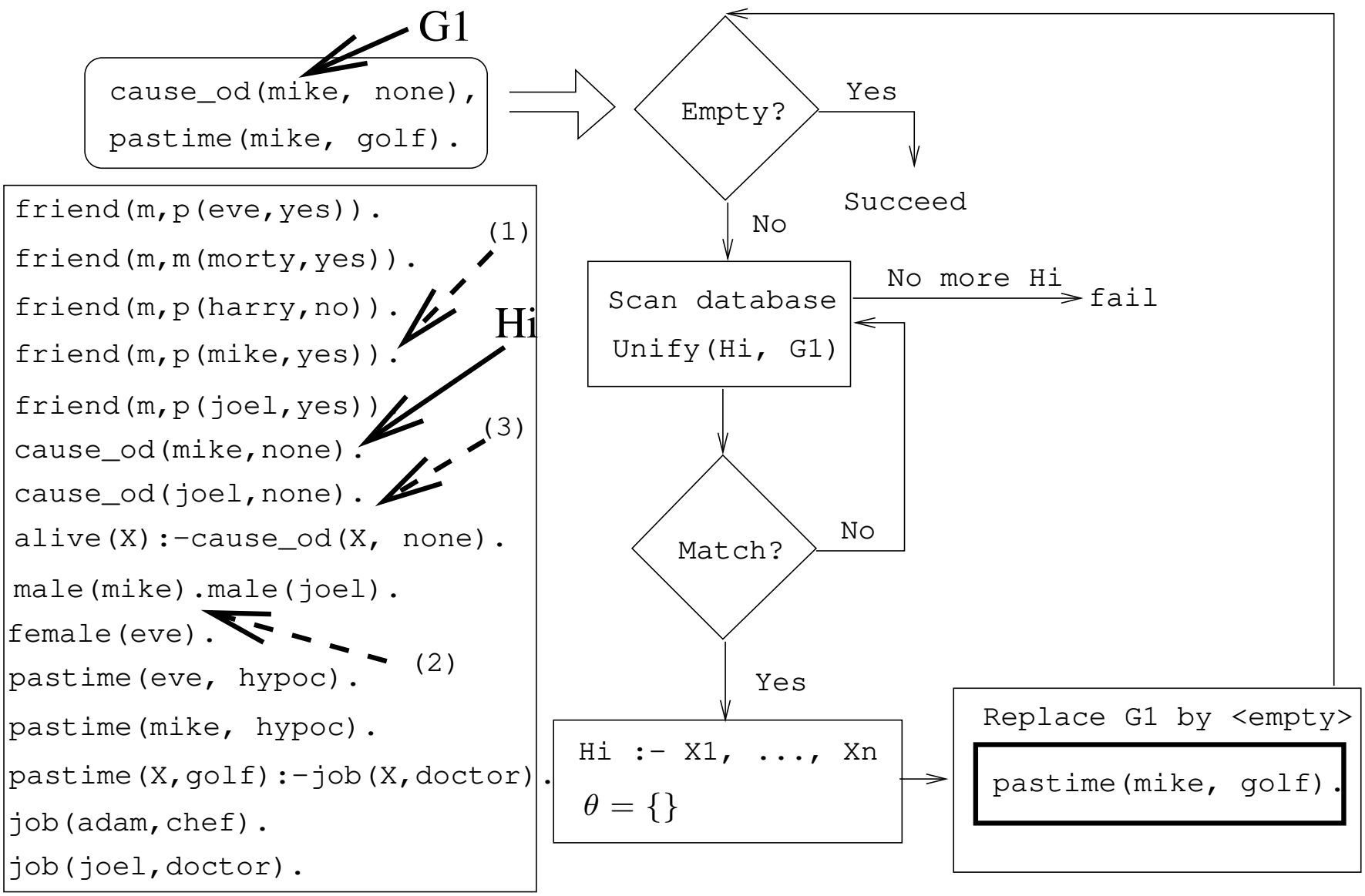

friend(maggie, p(B, yes)),
male(B), alive(B),
pastime(B, golf).
G1
Empty?
Yes
Succeed
No
Scan database
Unify(Hi, G1)
No more Hi
fail
Match?
No
Yes
Hi
friend(m,p(eve,yes)).
friend(m,m(morty,yes)).
friend(m,p(harry,no)).
friend(m,p(mike,yes)).
friend(m,p(joel,yes)).
cause_od(mike,none).
cause_od(joel,none).
alive(X):-cause_od(X, none).
male(mike).male(joel).
female(eve).
pastime(eve, hypocondriac).
pastime(mike, hypocondriac).
pastime(X,golf):-job(X,doctor).
job(adam,chef).
job(joel,doctor).
Hi :- X1, ..., Xn
θ = {B=eve}
Replace G1 by <empty>
Substitute vars from θ
male(eve), alive(eve),
pastime(eve, golf).

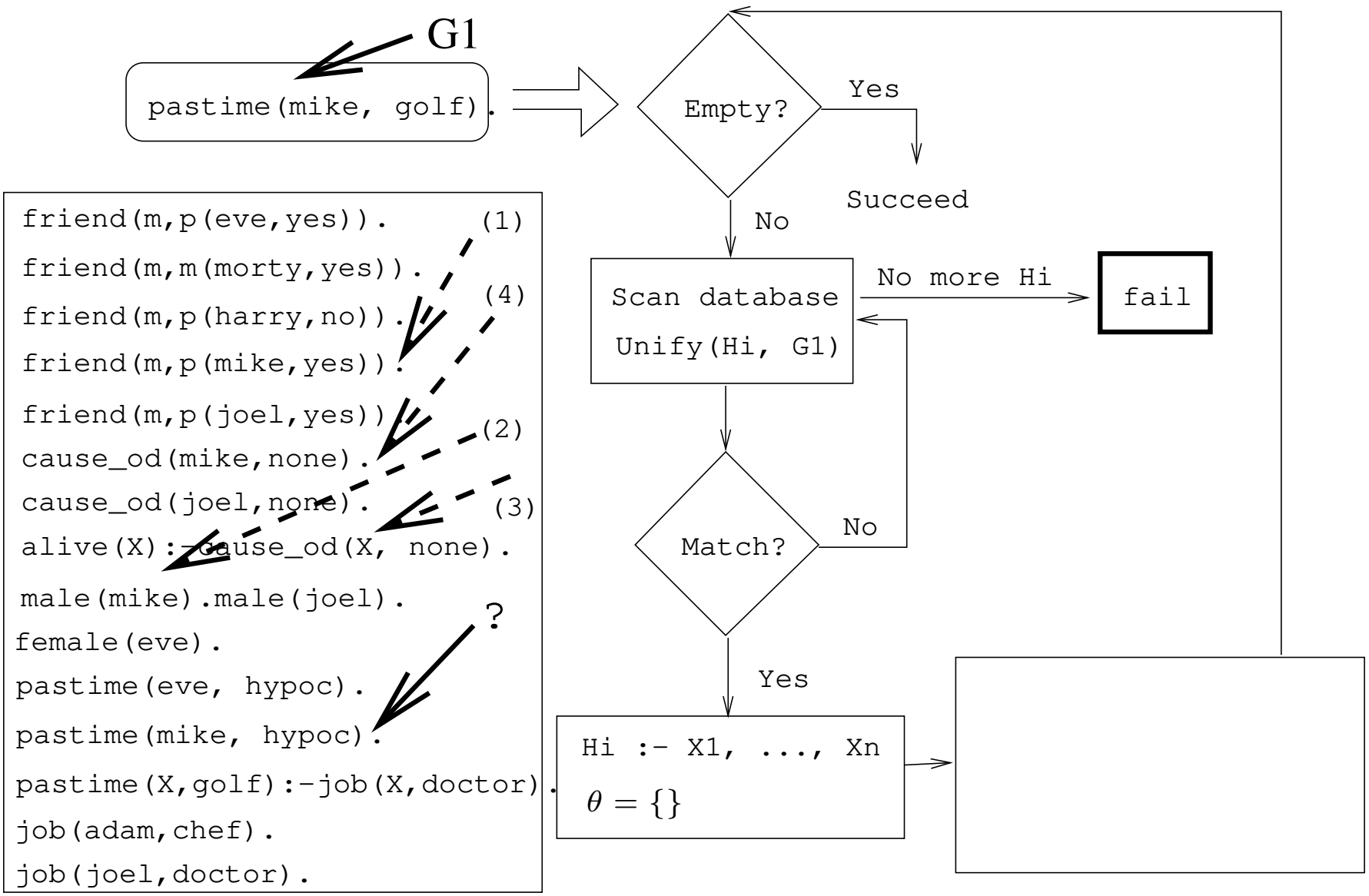

G1
male(eve), alive(eve),
pastime(eve, golf).
Empty?
Yes
Succeed
No
(1)
friend(m,p(eve,yes)).
friend(m,m(morty,yes)).
friend(m,p(harry,no)).
friend(m,p(mike,yes)).
friend(m,p(joel,yes)).
cause_od(mike,none).
cause_od(joel,none).
alive(X):-cause_od(X, none).
male(mike).male(joel).
female(eve).
pastime(eve, hypocondriac).
pastime(mike, hypocondriac).
pastime(X,golf):-job(X,doctor).
job(adam,chef).
job(joel,doctor).
?
Scan database
Unify(Hi, G1)
No more Hi
fail
Match?
No
Yes


friend(maggie, p(B, yes)),
male(B), alive(B),
pastime(B, golf).
G1
Empty?
Yes
Succeed
No
Scan database
Unify(Hi, G1)
No more Hi
fail
Match?
No
Yes
Hi
friend(m,p(eve,yes)).
friend(m,m(morty,yes)).
friend(m,p(harry,no)).
friend(m,p(mike,yes)).
friend(m,p(joel,yes)).
cause_od(mike,none).
cause_od(joel,none).
alive(X):-cause_od(X, none).
male(mike).male(joel).
female(eve).
pastime(eve, hypocondriac).
pastime(mike, hypocondriac).
pastime(X,golf):-job(X,doctor).
job(adam,chef).
job(joel,doctor).
Hi :- X1, ..., Xn
θ = {B=mike}
Replace G1 by <empty>
Substitute vars from θ
male(mike),alive(mike),
pastime(mike, golf).


G1
male(mike), alive(mike),
pastime(mike, golf).
Empty?
Yes
Succeed
No
Scan database
Unify(Hi, G1)
No more Hi
fail
Match?
No
Yes
Hi :- X1, ..., Xn
θ = {}
Replace G1 by <empty>
Substitute vars from θ
alive(mike),
pastime(mike, golf).
friend(m,p(eve,yes)).
friend(m,m(morty,yes)).
friend(m,p(harry,no)).
friend(m,p(mike,yes)).
friend(m,p(joel,yes)).
cause_od(mike,none).
cause_od(joel,none).
alive(X):-cause_od(X, none).
male(mike).male(joel).
female(eve).
pastime(eve, hypocondriac).
pastime(mike, hypocondriac).
pastime(X,golf):-job(X,doctor).
job(adam,chef).
job(joel,doctor).
(1)
Hi


G1
alive(mike),
pastime(mike, golf).
Empty?
Yes
Succeed
No
Scan database
Unify(Hi, G1)
No more Hi
fail
Match?
No
Yes
Hi :- X1, ..., Xn
θ = {X=mike}
Replace G1 by
<cause_od(X,none)>
cause_od(mike, none),
pastime(mike, golf).
friend(m,p(eve,yes)).
friend(m,m(morty,yes)).
friend(m,p(harry,no)).
friend(m,p(mike,yes)).
friend(m,p(joel,yes)).
cause_od(mike,none).
cause_od(joel,none).
alive(X):-cause_od(X, none).
male(mike).male(joel).
female(eve).
pastime(eve, hypocondriac).
pastime(mike, hypocondriac).
pastime(X,golf):-job(X,doctor).
job(adam,chef).
job(joel,doctor).
(1)
(2)
Hi


G1
cause_od(mike, none),
pastime(mike, golf).
Empty?
Yes
Succeed
No
Scan database
Unify(Hi, G1)
No more Hi
fail
Match?
No
Yes
Hi :- X1, ..., Xn
θ = {}
Replace G1 by <empty>
pastime(mike, golf).
Hi
(1)
(2)
(3)
friend(m,p(eve,yes)).
friend(m,m(morty,yes)).
friend(m,p(harry,no)).
friend(m,p(mike,yes)).
friend(m,p(joel,yes))
cause_od(mike,none).
cause_od(joel,none).
alive(X):-cause_od(X, none).
male(mike).male(joel).
female(eve).
pastime(eve, hypoc).
pastime(mike, hypoc).
pastime(X,golf):-job(X,doctor).
job(adam,chef).
job(joel,doctor).

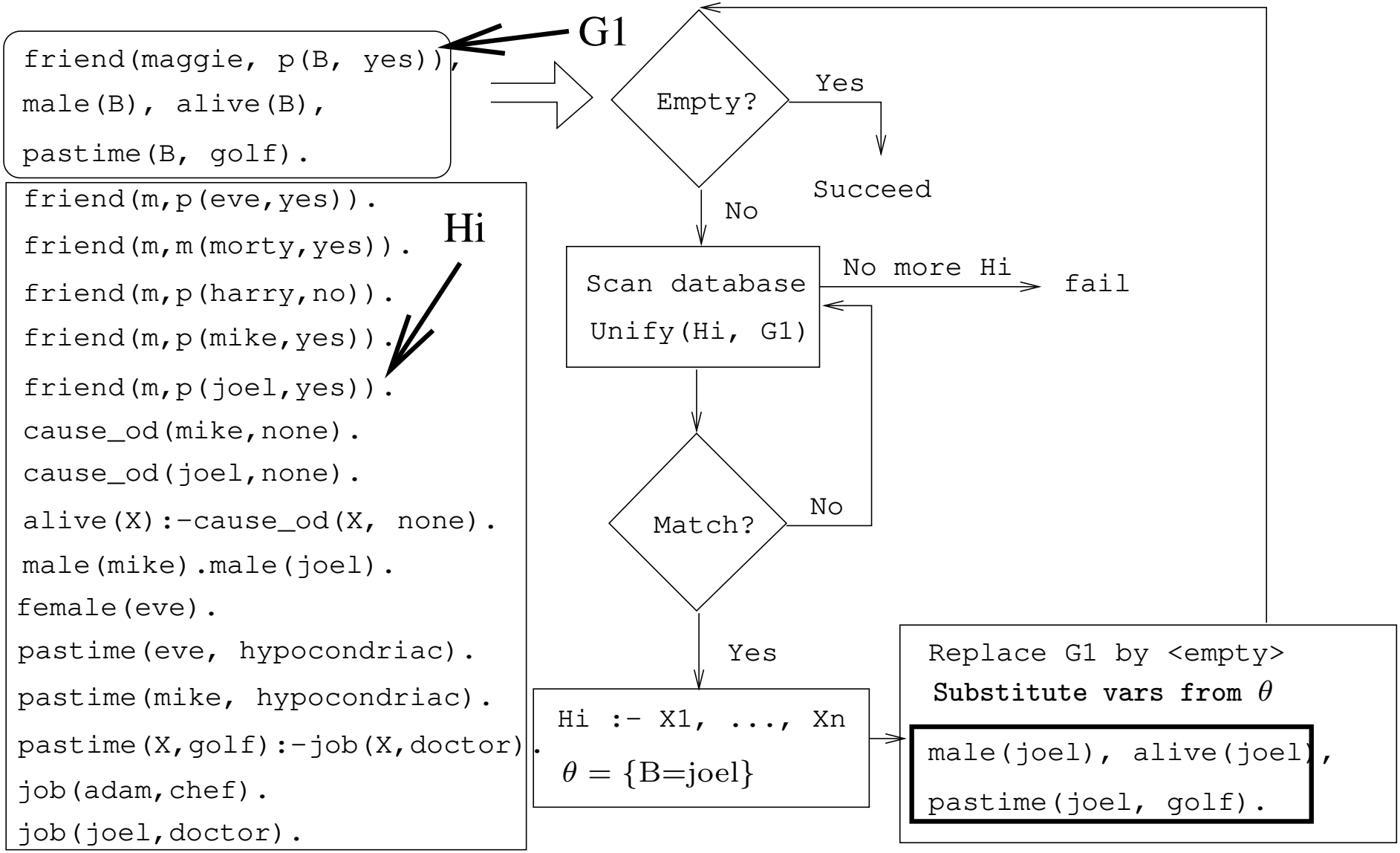

G1
pastime(mike, golf).
Empty?
Yes
Succeed
No
Scan database
Unify(Hi, G1)
No more Hi
fail
Match?
No
Yes
Hi :- X1, ..., Xn
$\theta = \{\}$
friend(m,p(eve,yes)).
friend(m,m(morty,yes)).
friend(m,p(harry,no)).
friend(m,p(mike,yes)).
friend(m,p(joel,yes)).
cause_od(mike,none).
cause_od(joel,none).
alive(X):-cause_od(X, none).
male(mike).male(joel).
female(eve).
pastime(eve, hypoc).
pastime(mike, hypoc).
pastime(X,golf):-job(X,doctor).
job(adam,chef).
job(joel,doctor).
(1)
(4)
(2)
(3)
?

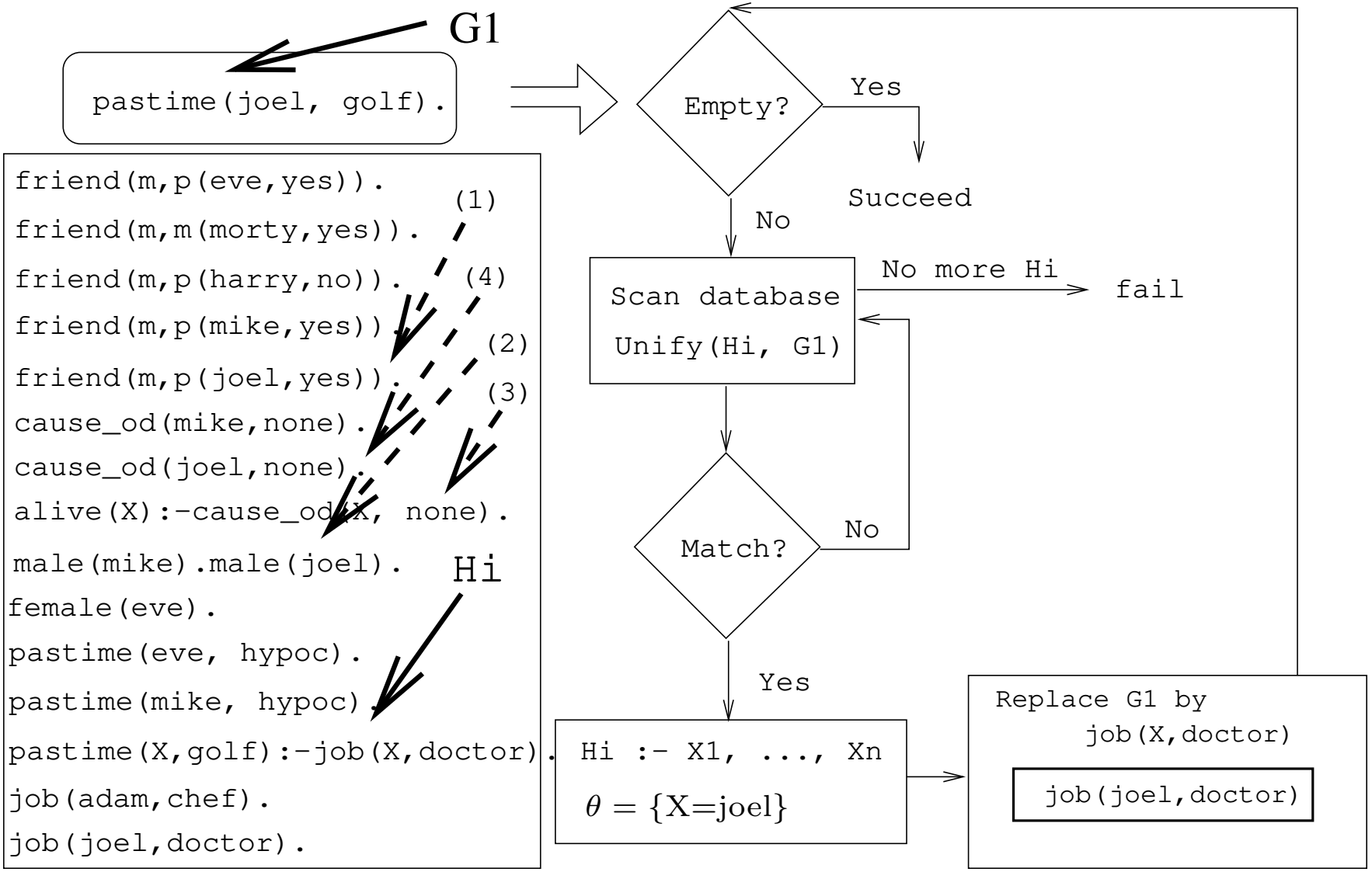
Northern Exposure Example. . .

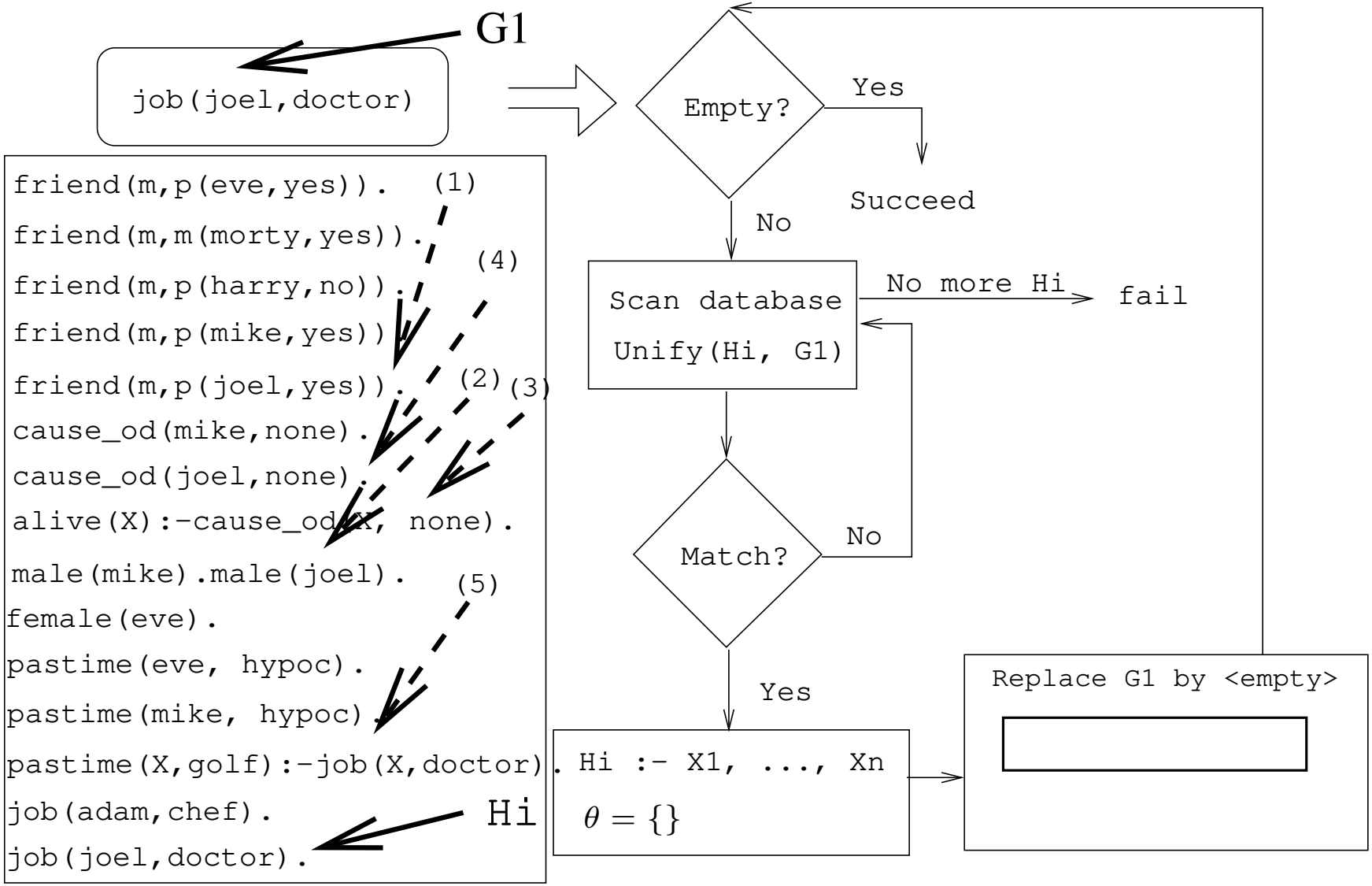
- We skip a step here.
- `pastime(mike, golf)` unifies with

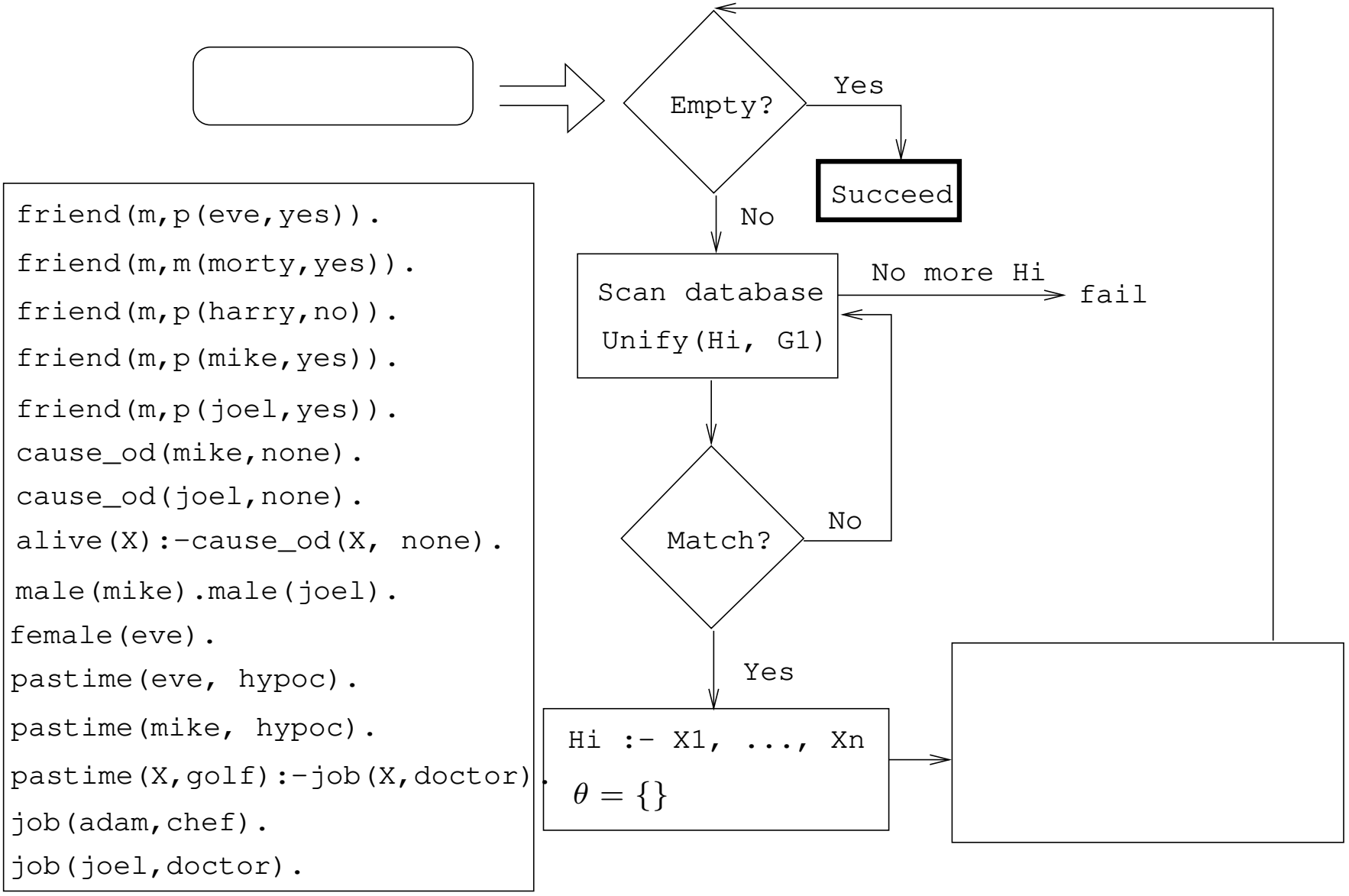
```
pastime(X, golf) :- job(X, doctor).
```

  .
- However, `job(mike, doctor)` fails, and we backtrack all the way up to the original query.


G1
friend(maggie, p(B, yes)),
male(B), alive(B),
pastime(B, golf).
Empty?
Yes
Succeed
No
Scan database
Unify(Hi, G1)
No more Hi
fail
Match?
No
Yes
Hi
friend(m,p(eve,yes)).
friend(m,m(morty,yes)).
friend(m,p(harry,no)).
friend(m,p(mike,yes)).
friend(m,p(joel,yes)).
cause_od(mike,none).
cause_od(joel,none).
alive(X):-cause_od(X, none).
male(mike).male(joel).
female(eve).
pastime(eve, hypocondriac).
pastime(mike, hypocondriac).
pastime(X,golf):-job(X,doctor).
job(adam,chef).
job(joel,doctor).
Hi :- X1, ..., Xn
θ = {B=joel}
Replace G1 by <empty>
Substitute vars from θ
male(joel), alive(joel),
pastime(joel, golf).


G1
pastime(joel, golf).
Empty?
Yes
Succeed
No
Scan database
Unify(Hi, G1)
No more Hi
fail
Match?
No
Yes
Hi
Hi :- X1, ..., Xn
θ = {X=joel}
Replace G1 by
job(X,doctor)
job(joel,doctor)
friend(m,p(eve,yes)).
friend(m,m(morty,yes)).
friend(m,p(harry,no)).
friend(m,p(mike,yes)).
friend(m,p(joel,yes)).
cause_od(mike,none).
cause_od(joel,none).
alive(X):-cause_od(X, none).
male(mike).male(joel).
female(eve).
pastime(eve, hypoc).
pastime(mike, hypoc).
pastime(X,golf):-job(X,doctor).
job(adam,chef).
job(joel,doctor).
(1)
(2)
(3)
(4)


G1
job(joel,doctor)
Empty?
Yes
Succeed
No
Scan database
Unify(Hi, G1)
No more Hi
fail
Match?
No
Yes
Hi :- X1, ..., Xn
$\theta = \{\}$
Replace G1 by <empty>
friend(m,p(eve,yes)).
friend(m,m(morty,yes)).
friend(m,p(harry,no)).
friend(m,p(mike,yes)).
friend(m,p(joel,yes)).
cause_od(mike,none).
cause_od(joel,none).
alive(X):-cause_od(X, none).
male(mike).male(joel).
female(eve).
pastime(eve, hypoc).
pastime(mike, hypoc).
pastime(X,golf):-job(X,doctor).
job(adam,chef).
job(joel,doctor).
(1)
(2)
(3)
(4)
(5)
Hi


Empty?
Yes
Succeed
No
Scan database
Unify(Hi, G1)
No more Hi
fail
Match?
No
Yes
Hi :- X1, ..., Xn
$\theta = \{\}$
friend(m,p(eve,yes)).
friend(m,m(morty,yes)).
friend(m,p(harry,no)).
friend(m,p(mike,yes)).
friend(m,p(joel,yes)).
cause_od(mike,none).
cause_od(joel,none).
alive(X):-cause_od(X, none).
male(mike).male(joel).
female(eve).
pastime(eve, hypoc).
pastime(mike, hypoc).
pastime(X,golf):-job(X,doctor).
job(adam,chef).
job(joel,doctor).

Readings and References

- Read Clocksin-Mellish, Section 4.1.
- See http://www.moosefest.org for information about the annual Moosefest.
- See http://members.lycos.co.uk/janineturner/engl/index.html for pictures of Janine Turner, who plays Maggie.
- See http://home.comcast.net/~mcnotes/mcnotes.html for show transcripts.

Summary

Prolog So Far...

- A term is either a
  - a constant (an atom or integer)
  - a variable
  - a structure
- Two terms *match* if
  - there exists a variable substitution θ which makes the terms identical.
- Once a variable becomes instantiated, it stays instantiated.
- Backtracking *undoes* variable instantiations.
- Prolog searches the database sequentially (from top to bottom) until a matching clause is found.