Systems and Solving Techniques for Knowledge Representation – Datalog –

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#### A logic language for querying databases

- Overcomes some limits of Relational Algebra and SQL
  - $\rightarrow$ Recursive definitions

Why Datalog?

# What is Datalog?

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Why Datalog?The basic fragment of ASP

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## Why Datalog?

Rule:

 $head(\overline{H}) := body_1(\overline{X_1}), \dots, body_n(\overline{X_n}).$ 

Intuitively:

infer  $head(\overline{h})$  if  $body_1(\overline{x_1}), \ldots, body_n(\overline{x_n})$  is true.

Fact:

A rule with empty body (:- symbol is omitted)

ightarrow Facts are true and model the input database  $\leftarrow$ 

## Variables:

are allowed in atom's arguments, Prolog-like syntax

## Safety:

all variables must occur in the body

#### Example

#### Program and query:

father(X) := parent(X, Y), male(X).

Database:

```
male(rob).
parent(rob, ann).
parent(mary, ann).
```

#### **Query Result:**

father(rob).

# Practice

#### Download a (Datalog) implementation (clasp)

http://potassco.sourceforge.net/

We need also a grounder (gringo) http://potassco.sourceforge.net/

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#### Example (Reachable airports)

**Input:** A set of direct connections between some cities represented by *connected*(\_,\_). [or,*connected*/2.]

**Query:** Retrieve all the cities reachable by flight from Vienna airport, through a direct or undirect connection.

...can you write an SQL query?

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#### Datalog:

reaches(vienna, B) :- connected(vienna, B).

reaches(vienna, C) :- reaches(vienna, B), connected(B, C)

# Datalog Programs (1)

## **Datalog Program:**

- A set of rules
- EDB: predicates appearing only in bodies or in facts
- IDB : predicates defined (also) by rules

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% if there is an edge from X to Y
% then X is reachable from Y
reachable(X, Y) := edge(X, Y).
```

% Reachability is transitive reachable(X, Y) := reachable(X, Z), edge(Z, Y).

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#### Intuitive reasoning: (bottom-up evaluation)

"Start with the facts in the EDB and iteratively derive facts for IDBs until no new fact is derived."

#### Example (Ancestor)

```
Input: parent relation modeled by parent(_,_). Problem: Define the relation of arbitrary ancestors.
```

#### Solution 1:

ancestor(A, B) :- parent(A, B). ancestor(A, C) :- ancestor(A, B), ancestor(B, C).

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Solution 1:

ancestor(A, B) :- parent(A, B). ancestor(A, C) :- ancestor(A, B), ancestor(B, C).

Solution 2:

ancestor(A, B) :- parent(A, B). ancestor(A, C) :- ancestor(A, B), parent(B, C).

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Solution 3: Declarative: Atoms' and Rules' order is immaterial!

ancestor(A, C) :- ancestor(A, B), parent(B, C). ancestor(A, B) :- parent(A, B).

#### Arithmetic and comparison operators

## Example (Fibonacci numbers) fib(1,0). fib(2,1). fib(N+2,Y1+Y2) := fib(N,Y1), fib(N+1,Y2).

For recursive definitions an upper bound for integers has to be specified, either as a system setting, or as a domain definition.

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#### Example (No Peroni here!)

**Input:** Information about bars and drinks represented by facts of the form *type(drink, name). sells(bar, drink)* 

Query: Retrieve all bars that do not sell Peroni

...can you write an Datalog query?

#### Example (No Peroni here!)

```
Input: Information about bars and drinks represented by
facts of the form
type(drink, name). sells(bar, drink)
Query: Retrieve all bars that do not sell Peroni
Datalog:
noPeroni(Bar) :- sells(Bar, Drink),
                    not sellsPeroni(Bar).
sellsPeroni(Bar) :- sells(Bar, Drink), type(Drink, peroni).
```

# **Datalog with Negation**

## Rule:

 $head(\overline{H}) := body_1(\overline{X_1}), \dots, body_n(\overline{X_n}),$ not  $body_{n+1}(\overline{X_{n+1}}), \dots, not \ body_m(\overline{X_m}).$ 

**Positive and Negative Body:** 

 $body_1(\overline{x_1}), \dots, body_n(\overline{x_n}) \leftarrow \text{positive body} \\ body_{n+1}(\overline{x_{n+1}}), \dots, body_m(\overline{x_m}). \leftarrow \text{negative body}$ 

## Intuitively:

infer  $head(\overline{h})$  if all atoms in the positive body are true and all atoms in the negative body are false

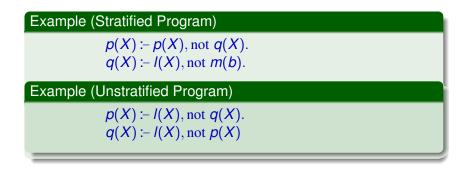
#### Safety:

all variables must occur in a positive body literal

#### Stratification (intuitive):

negation must not be involved in recursive definitions!

## Stratification (i.e., no recursion trough negation)



### Needed Restrictions for Safety ...

#### Safety:

$$s(X) \coloneqq not r(X).$$
  
 $s(X, Y) \coloneqq r(Y).$   
 $s(X, Y) \coloneqq r(X), Y = Y.$ 

## Intuitively:

In each of these cases the result is infinite !?!

More on this later...

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