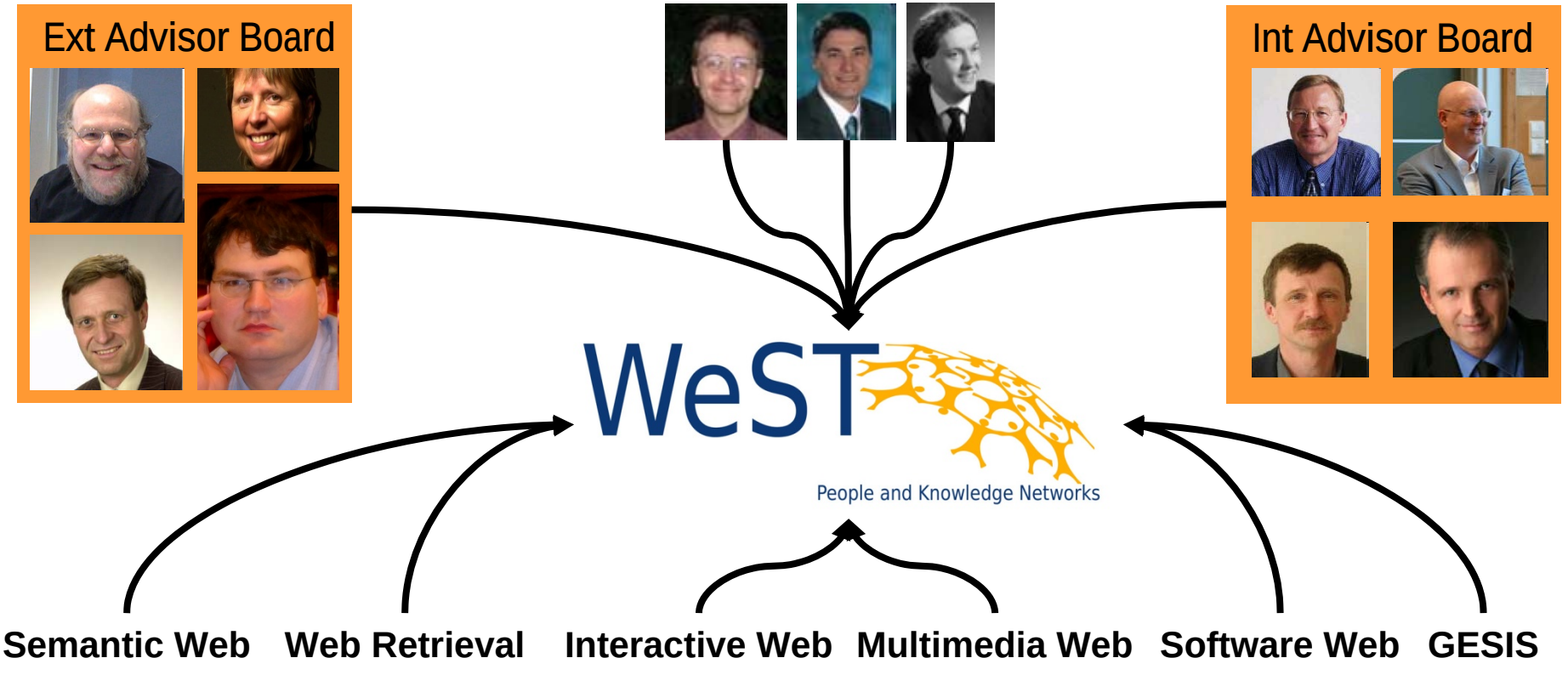
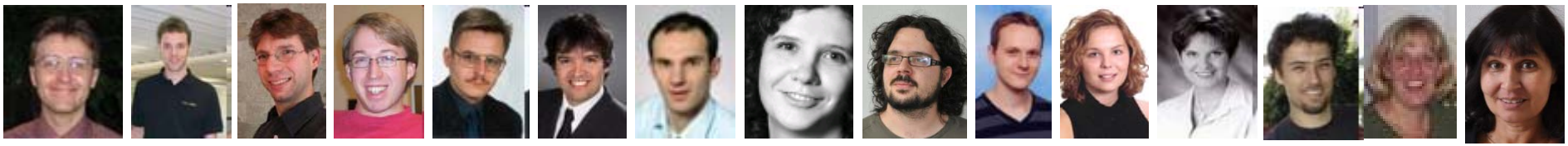
Advanced Data Modeling

Steffen Staab

Institut WeST – Who we are!





Contact:

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Scheduling: via email to hissnauer@uni-koblenz.de

Teaching assistant: Gerd Gröner

http://west.uni-koblenz.de/Teaching/ss11/adm11/

For whom?

Advanced Data Modeling

Addressees:

Master Inf/CV

Diplom Hauptstudium Inf/CV

Lecture INSS02 is Part of the „Schwerpunkt“ Data & Knowledge Engineering in the Master‘s Programme of Computer Science

Bachelor students may elect advanced courses such as Advanced Data Modeling as „Wahl-/Wahlpflicht“

Open Questions

- English vs German

- Tutorial slot
  - Tuesday 12-14 or
  - Friday 10-12 ?

- Bring your laptop tomorrow!

Examination

- Tutorials:
  - for improving understanding and getting hands on experience
  - Hand in excercises
    - 75% fulfillment: 1 grade level better (e.g. 1.7 -> 1.3)
    - 90% fulfillment: 2 grade levels better (e.g. 2.0 -> 1.3)

- Probably oral, maybe written:
  - between mid June and mid July.
  - Your own responsibility to schedule an appointment via Mrs Hissnauer
  - No later first examinations in Advanced Data Modeling
  - no admission criteria, but do not expect to pass if you did not do the assignments

Organizational Issues

Monday: B016
Tuesday lecture: K208
Tuesday tutorial: G210

Mon April 18, 14-16, Lecture 1
Tue April 19, 10-12, Lecture 2
Tue April 19, 12-14, Tutorial 1

Mon April 25, Easter Monday
Tue April 26, 10-12, Lecture 3
Tue April 26, 12-14, Tutorial 2

Mon May 2, Lecture 4
Tue May 3, 10-12, Lecture 5
Tue May 3, 12-14, Tutorial 3

Mon May 9, Lecture 6
Tue May 10, 10-12, Lecture 7
Tue May 10, 12-14, Tutorial 4

Mon May 16, Lecture 8
Tue May 17, 10-12, Lecture 9
Tue May 17, 12-14, Tutorial 5

Mon May 23, Tutorial 6
Tue May 24, 10-12, Lecture 10
Tue May 24, 12-14, Tutorial 7

Mon May 30, Lecture 11
Tue May 31, Lecture 12
Tue June 1, Tutorial 8

Mon June 7, - no lecture –
Tue June 8, - no lecture -
Tue June 8, Tutorial 9

June 11-19: Pentecost – no lectures

Mon June 20, Lecture 13
Tue June 21, Lecture 14
Tue June 21, Tutorial 10

Assumption

- Did you participate in Introduction to Databases?
- Did you participate in the Logics course?

Structure of the lecture

- Logics for Data Engineering
- Relational data model;
- Deductive data model;
- Recursive definitions and their semantics

- Provenance queries
- Policy languages

Why Logics for Data Engineering?

- Many current applications:
  - Hidden part of advanced databases like Oracle, DB2,…
  - Policy languages / Access control
  - Ontologies & Semantic Web
  - Software engineering: OCL
- Why?
  - Generalization of other data models
    - Relational
    - Semi-structured (RDF, XML, OEM,…)
  - Well-understood theory
    - Yet still evolving….!

Deductive Databases

- evolved during the 1980s, based on the ideas developed in **relational databases** and **logic programming**.

- developed with the aim of **increasing the expressive power** of relational query languages, and in particular in connection with the inability of the latter to **express recursive queries.**

- navigational (early DBMS);
- declarative (relational DBMS).

Why logics?

- Logic tried to solve problems similar to those arising in
- foundations of databases:

- how to formalize the application world (**language**);

- How to express its properties (**semantics, model theory**);

- How to reason about these properties (**proof theory**).

Why logics?

- Logic can handle in a **uniform framework**
- recursive definitions;
- integrity constraint;
- deduction, induction and abduction;
- Models for complex values . . .

Informal overview of deductive databases

- Extensionally defined relations.
- Intensionally defined relations.
- Integrity constraints.
- Recursion.
- Complex values.
- Negation

Extensionally defined relations

- **Extensional** definition:
  by explicit enumeration of all tuples in the relation.

- (”Maier”, ”Mozartstrasse”, 678);
- …
- (”Schmidt”, ”Raiffeisenstrasse”, 857);
- …

Extensionally defined relation

- In deductive databases we use the language of first-order logic and represent this relation by a set of **facts**:

- entry(”Maier”, ”Mozartstrasse”, 678);
- …
- entry(”Schmidt”, ”Raiffeisenstrasse”, 857);
- …

Extensional database

The **extensional database** defines relations by sets of facts, for example

hasHighestDegree(”Maier”, BSc);
hasHighestDegree(”Schmidt”, MSc);
…
higherDegree(MSc,BSc);
…

Analogue of **tables** in relational databases.

Suppose we want to define a relation **personWithHigherDegree** among persons:

Person *A* has higher degree than person *B* **if**

the highest degree of *A* is higher than
the highest degree of *B*.

Extensional definition

personWithHigherDegree(”Schmidt”,”Maier”).
personWithHigherDegree(”Maier”,”Kunz”).
…

is dangerous
(**too large**, may become **inconsistent** after updates).

Rephrase

For each pair of people *A*, *B*,
A has higher degree than *B* **if**
the highest degree of *A* is *DA* **and**
the highest degree of *B* is *DB* **and**
DA is a higher degree than *DB*.

Clause (rule)

```
personWithHigherDegree(A,B) :-        % head of the clause

hasHighestDegree(A,DA),               % body
hasHighestDegree(B,DB),               % of the
higherDegree(DA,DB).                  % clause
```

```
SELECT
    D1.person, D2.person
FROM
    hasHighestDegree D1,
    hasHighestDegree D2,
    higherDegree
WHERE
    D1.degree = higherDegree.higher AND
    D2.degree = higherDegree.lower
```

The relation personWithHigherDegree holds between objects *A, B*

if

the relation hasHighestDegree holds between objects *A, DA*

and

the relation asHighestDegree holds between objects *B, DB*

and

the relation higherDegree holds between objects *RA,RB*.

Variables

For all objects **A, B, DA, DB**

the relation personWithHigherDegree holds between objects
A, B
if

the relation hasHighestDegree holds between objects ***A, DA***
and

the relation asHighestDegree holds between objects ***B, DB***
and

the relation higherDegree holds between objects ***RA,RB***.

subordinate(*O*, president) :- officer(*O*).

Here *O* is a variable, while president is a **constant**.

How to say this syntactically?

Different conventions:

Possibility 1: All variables are explicitly quantified

Possibility 2: Variables are implicitly quantified (universally or existentially – needs to be agreed by convention)

Sets of variables and constants are defined as such

Disjunction

How to express **every human is either a woman or a man**?

human(*A*) :-
    man(*A*).

human(*A*) :-
    woman(*A*).

Negation

How to express that every doctor has the same qualification as Doctor No, with the exception of Doctor No himself?

```
sameAs(A,A) :- Object(A).

sameQualification(A,B) :-
    hasHighestDegree(A, D),
    hasHighestDegree(B, D),
    notSameAs(A,B).

hasHighestDegree(DrNo, PhD).
```

Negation

Use negation:

```
sameQualification(A,B) :-
    hasHighestDegree(A, D),
    hasHighestDegree(B, D),
    not SameAs(A,B).
```

Negation is handled using the closed world assumption.

:- likes(*X, Y*), not likes(*Y, X*).

:- sameQualification(drNo, Y).

```
connected(StartPoint, EndPoint) :-
    arc(StartPoint, EndPoint).

connected(StartPoint, EndPoint) :-
    arc(StartPoint, NextPoint),
    connected(NextPoint, EndPoint).
```

StartPoint and EndPoint are connected

if

StartPoint and EndPoint are connected by an arc

or

there exists an intermediate point NextPoint such that

StartPoint and NextPoint are connected by an arc **and**

NextPoint and EndPoint are connected.

Each class has at least one lecturer:

$\forall x\ (\text{class}(x) \rightarrow \exists y\ \textit{lecturer}(y, x))$.

Each class has at most one lecturer:

$\forall x(\text{class}(x) \rightarrow\ \forall y\ \forall z(\text{lecturer}(y, x) \wedge \text{lecturer}(z, x) \rightarrow y{=}z)$.

Complex values

```
route(StartPoint, EndPoint, [StartPoint, EndPoint]) :-
    arc(StartPoint, EndPoint).

route(StartPoint, EndPoint, [StartPoint|Route]) :-
    arc(StartPoint, NextPoint),
    route(NextPoint, EndPoint, Route).
```

Problems

Combinations of following three features create problems with defining semantics of deductive databases and designing query answering algorithms for them:

Negation;

Recursion;

Complex values.

Restrictions may be required on the use of (combinations of) these features.

SWI Prolog:

http://www.swi-prolog.org/

Soccer database

% EXTENSIONAL DATABASE

% Relation nextLeague describes the hierarchy of leagues in

% UK

nextLeague(league2, league1).

nextLeague(league1, championship).

nextLeague(championship, premier).

% the list of clubs

club(arsenal).

club(watford).

club(leedsU).

club(miltonKeynesDons).

% the list of leagues of clubs

league(arsenal, premier).

league(watford, championship).

league(leedsU, league1).

league(miltonKeynesDons, league2).

% the list of players and where they are playing

```
player(andy,arsenal).
player(wim,watford).
player(liam, leedsU).
player(mike, miltonKeynesDons).
```

```
% some players foul other players
foul(andy,wim).
foul(andy,bert).
foul(andy,chris).
foul(andy,dan).
foul(wim, andy).
foul(wim, dan).
```

% INTENSIONAL DATABASE

% Relation nextLeagues describes the order on leagues

% It is defined as the transitive closure of nextLeague

```
higherLeague(LowerLeague, HigherLeague) :-
    nextLeague(LowerLeague, HigherLeague).

higherLeague(LowerLeague, HigherLeague) :-
    nextLeague(LowerLeague, MiddleLeague),
    higherLeague(MiddleLeague, HigherLeague).
```

```
% A higher-leagued club is a club who is in a higher league

higherLeaguedClub(Higher, Lower) :-
    league(Higher, HigherLeague),
    league(Lower, LowerLeague),
    higherLeague(LowerLeague, HigherLeague).
```

```
% likes is a relation among players.

% (i) every player likes himself
like(Player, Player) :-
    player(Player).

% (ii) every player likes all players in higher-ranked clubs
like(Lower, Higher) :-
    player(Lower, LowerClub),
    player(Higher, HigherClub),
    higherRankedClub(HigherClub, LowerClub).
```

```
% (iii) a player likes a lower-ranked player when
% players of the lower-ranked club
% do not foul other players of his club

likes(Higher, Lower) :-
    player(Higher, HigherClub),
    player(Lower,LowerClub),
    higherRankedClub(HigherClub, LowerClub),
    not hasPlayerWhoFoulsSomePlayerFrom(LowerClub,
    HigherClub).
```

% an auxiliary relation: hasPlayerWhoFoulsSomePlayerFrom

```
hasPlayerWhoFoulsSomePlayerFrom(Club1, Club2) :-
    player(Player1, Club1),
    player(Player2, Club2),
    foul(Player1, Player2).
```

% INTEGRITY CONSTRAINTS

% every club has a league

$\forall x(\text{club}(x) \rightarrow \exists y\ \textit{league}(x, y))$.

% only premier league player may foul more than one player

$\forall p, c, z1, z2$

$(\text{player}(p,c) \wedge \text{foul}(p, z1) \wedge \text{foul}(p, z2)$

$\rightarrow$

$z1 = z2 \vee \text{league}(c, \textit{premier}))$.