From Extended Entity-Relationship schemata to illustrative instances

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please visit the companion Web site:
http://mag.dsi.unimi.it/EER2instances

May 21, 2008
Illustrative Instances

long-term research topic:
apply logic programming to automated reasoning about projects diagrams: UML and [E]ER.

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Given a set of constraints representing an EER project, generate automatically an example instance showing how the final database will (likely) look like.
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Given a set of constraints representing an EER project, generate automatically an example instance showing how the final database will (likely) look like.

Automated reasoning about project constraints: (relatively) easy to add them to our LP representation
both directions of research showcase DLV*
Informative Armstrong Data Bases (IADBs)

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Informative Armstrong Database

A *small* instance that satisfies exactly the same functional and inclusion dependencies that were found on the given (normally large) database instance. IADBs consist of *real tuples* that come from an input database which we want to *understand*.
Introduction

Literature: Armstrong Databases
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[Fagin-Vardi]
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[Fagin-Vardi]
An Armstrong Database is a *global Witness* from a *relational* schema.

1. Let $\Sigma$ a set of constraints over the schema
2. Let $\Sigma^*$ the set of logical consequences of $\Sigma$
3. An instance $\Theta$ is an ADB if
   a. $\forall \sigma \in \Sigma^*. \ \Theta \models \sigma$
   b. $\forall \sigma \notin \Sigma^*. \ \Theta \not\models \sigma$
Example (Fagin-Vardi): ADB

\[ \Sigma = \{ EMP \rightarrow DEPT, DEPT \rightarrow MGR \} \]

<table>
<thead>
<tr>
<th>Employee</th>
<th>Dept</th>
<th>Manager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hilbert</td>
<td>Math</td>
<td>Gauss</td>
</tr>
<tr>
<td>Pythagoras</td>
<td>Math</td>
<td>Gauss</td>
</tr>
<tr>
<td>Turing</td>
<td>Computer Science</td>
<td>von Neumann</td>
</tr>
<tr>
<td>Einstein</td>
<td>Physics</td>
<td>Gauss</td>
</tr>
</tbody>
</table>

Table: Armstrong Relation \( r \) for \( \Sigma \)

\( \Sigma^* \) contains the FD’s in \( \Sigma \)

The FD \( MGR \rightarrow DEPT \) is not an FD in \( \Sigma^* \), and indeed, \( r \) does not obey this FD, since \text{Gauss} is the Manager of two distinct departments (Math and Physics)
Example: EER schema

The schema describes employees (entity Employee) working (relationship Works_in) in departments (relationship Dept) of a firm, and managers (entity Manager) that are also employees, and manage (relationship Manages) departments. Managers who manage a department also work in the same department, as imposed by the is-a among the two relationships.
FROM EER to ERL

A new DTD for handling *is-a* between relationship
Step-by-step generation of the logic program

Given an EER $C$ our translation creates a Logic program $\pi_C$ with a step-by-step process that applies 15 translation rules.
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Translation

- **A..D** insert into $\pi_C$ facts and rules that capture the structure of a relational schema induced by $C$;
- **1..11** insert into $\pi_C$ rules that capture two essential aspects of EER:
  - inclusion dependencies, captured by logic programming constraints (on consistency);
  - the inheritance relation between entities (resp. relationships) which is captured by normal deductive rules.
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Implemented as a ERW interface:

```
> java -cp ER2DL.jar it.unimi.dsi.erw.ERtool < my-eer-project.xml --datalog
```
The semantics of an EER schema is defined by specifying all constraints imposed by EER constructs on databases that satisfy that schema.
From EER to Logic Programs: Modifying [Calì 07]

The semantics of an EER schema is defined by specifying all constraints imposed by EER constructs on databases that satisfy that schema.

First of all, we formally define a database schema from an EER diagram. Such a database schema is defined in terms of predicates: we define a relational database schema that encodes the properties of an EER schema $C$.

A. Each entity $E$ in $C$ has an associated predicate $E$ of arity 1.
B. Each attribute $A$ for an entity $E$ in $C$ has an associated predicate $A$ of arity 2, associating attribute values to entity instances.
C. Each relationship $R$ among the entities $E_1, \ldots, E_n$ in $C$ has an associated predicate $R$ of arity $n$.
D. Each attribute $A$ for a relationship $R$ among the entities $E_1, \ldots, E_n$ in $C$ has an associated predicate $A$ of arity $n + 1$, associating attribute values to $n$-tuples of entity instances.
Cont’d

Given a database schema $R$ for an EER schema $C$, Calì gives a semantics to each construct of the EER model by specifying what databases (i.e. extension of the predicates of $R$) satisfy the constraints imposed by the constructs of the EER diagram.

<table>
<thead>
<tr>
<th>EER construct</th>
<th>Relational constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>attribute $A/2$ for an entity $E$</td>
<td>$A[1] \subseteq E[1]$</td>
</tr>
<tr>
<td>attribute $A/(n + 1)$ for a relationship $R/n$</td>
<td>$A[1, \ldots, n] \subseteq R[a, \ldots, n]$</td>
</tr>
<tr>
<td>relationship $R$ with entity $E$ as $i$-th component</td>
<td>$R[j_i] \subseteq E[1]$</td>
</tr>
<tr>
<td>mandatory attribute $A/2$ of entity $E$</td>
<td>$E[1] \subseteq A[1]$</td>
</tr>
<tr>
<td>mandatory attribute $A/(n + 1)$ of relationship $R/n$</td>
<td>$R[1, \ldots, n] \subseteq A[1, \ldots, n]$</td>
</tr>
<tr>
<td>functional attribute $A/2$ of entity $E$</td>
<td>$\text{key}(A) = {1}$</td>
</tr>
<tr>
<td>functional attribute $A/(n + 1)$ of a relationship $R/n$</td>
<td>$\text{key}(A) = {1, \ldots, n}$</td>
</tr>
<tr>
<td>is-a relation between entities $E_1$ and $E_2$</td>
<td>$E_1[1] \subseteq E_2[1]$</td>
</tr>
<tr>
<td>is-a relation between relationships $R_1$ and $R_2$, where components $1, \ldots, n$ of $R_1$ correspond to components $j_1, \ldots, j_n$ of $R_2$</td>
<td>$R_1[1, \ldots, n] \subseteq R_2[j_i, \ldots, j_n]$</td>
</tr>
<tr>
<td>mandatory participation as $c$-th component of an entity $E$ in a relationship $R$</td>
<td>$E[1] \subseteq R[j]$</td>
</tr>
<tr>
<td>functional participation as $c$-th component of an entity $E$ in a relationship $R$</td>
<td>$\text{key}(R) = {c}$</td>
</tr>
</tbody>
</table>
Our method, By Example

Step A..D:

Step A. 
employee(emp).
manager(man).
department(dept).

Step B. 
emp_name(emp,emp_name).
department_name(dept,department_name).

Step C. 
works_in(emp,dept).
manages(manager,department).

Step D. 
since(employee,department,since).

Step 1..11:
capture special constraints (FDs, IDs e KDs).
Example 1: Defining the constraints

Step 1: emp_name[1] ⊆ employee[1]:

:- emp_name(Emp, Emp_name),
   not employee(Emp).

Step 2: since[1,2] ⊆ works_in[1,2]:

:- since(Emp, Dept, Since),
   not works_in(Emp, Dept).

Step 3: works_in[1] ⊆ employee[1]:

:- works_in(Emp, Dept), not employee(Emp).

Step 4: employee[1] ⊆ emp_name[1]:

:- employee(Emp), not
   emp_name(Emp, emp_name_of(Emp)).

Step 5: works_in[1,2] ⊆ since[1,2]:

:- works_in(Emp, Dept), not
   since(Emp, Dept, works_in_since(Emp, Dept)).

Step 6: does not apply to this example (it would simply generate a key constraint)

Step 7: does not apply to this example (it would simply generate a key constraint)

Step 8: Each manager is also an employee:

employee(Man) :- manager(Man).

Step 9: Each occurrence of Manages is also an occurrence of Works_in:

works_in(Emp, Dept) :- manages(Emp, Dept).

Step 10: employee[1] ⊆ works_in[1]:

:- employee(Emp),
   not participates(Emp, works_in, 1).
   participates(Emp, works_in, 1) :-
   dept(Dept), works_in(Emp, Dept).
   participates(Dept, works_in, 2) :-
   employee(Emp), works_in(Emp, Dept).

Step 11: key(works_in) = employee[1]:

:- works_in(Emp1, Dept1),
   works_in(Emp2, Dept2),
   Emp1 = Emp2,
   Dept1 != Dept2.
The target language of the mapping described in the previous Section is that of the novel DLV* inferential engine.
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DLV* is an extension of the well-know DLV inferential engine\textsuperscript{a} for deductive databases and disjunctive logic programming which supports functions, lists and sets.

\textsuperscript{a}DLV and its extensions, and related literature are available from http://www.dlvsystem.com/.
Finally...

relationship predicates reification are reified

```plaintext
from EER to illustrative instances 14/16
logic program execution

Relationship predicates reification are reified

--->dl my-eer-project.dlv

dlv [build BEN/Feb 8 2008 gcc 3.4.2 (mingw-special)]
{
  manages(man,dept),
  employee(emp),
  employee(man),
  manager(man),
  dept(dept),
  emp_name(emp,emp_name_of(emp)),
  emp_name(man,emp_name_of(man)),
  dept_name(dept,dept_name_of(dept)),
  works_in(emp,dept),
  works_in(man,dept),
  since(emp,dept,works_in_since(emp,dept)),
  since(man,dept,works_in_since(man,dept)),
  participates(emp,works_in,1),
  participates(man,works_in,1),
  participates(man,manages,1),
  participates(dept,works_in,2),
  participates(dept,manages,2)
}```
Results

Conceptual

Automated generation of illustrative instances for EER schema: It assists Database design exp. w.r.t. the non-expert.
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Technical
Modified XML representation of EER projects.
Modified translation from EER to Logic Programming
First-time application of DLV*
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Integration into ERW

1. Input: EER project in ERL encoding
2. Output:
   2.1 DLV* representation, an illustrative instance;
   2.2 SQL commands for DB creation, ready-made PHP pages and forms needed for populating the database and for maintenance.
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