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Introduction to Amos II

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Amos II Object-Relational DBMS

- Amos II developed at UDBL/LiTH
- Amos II runs on PCs under Windows and Linux
- Amos II uses *functional* query language *AmosQL*: Use *functions* to model data.
- Amos II system is a fast *main-memory DBMS*
- Amos II has single user or optional client-server configuration
- Amos II is *extensible*, i.e. foreign functions in e.g. C
- Amos II is a *mediator* system for *wrapping* and *integrating data* from other databases, files, streams, etc.
- Highly parallel data stream management system (DSMS) on top of Amos II, SCSQ
- Applications: Science, industry, etc.

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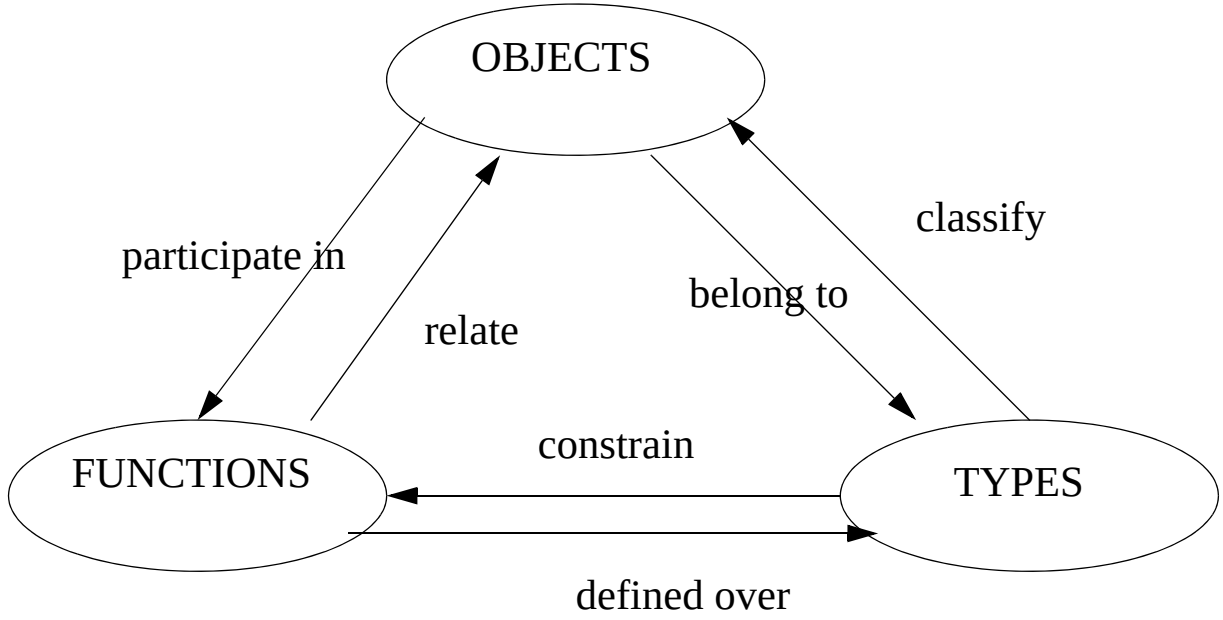
Amos II Data Model

Data Model

Basic elements in data model



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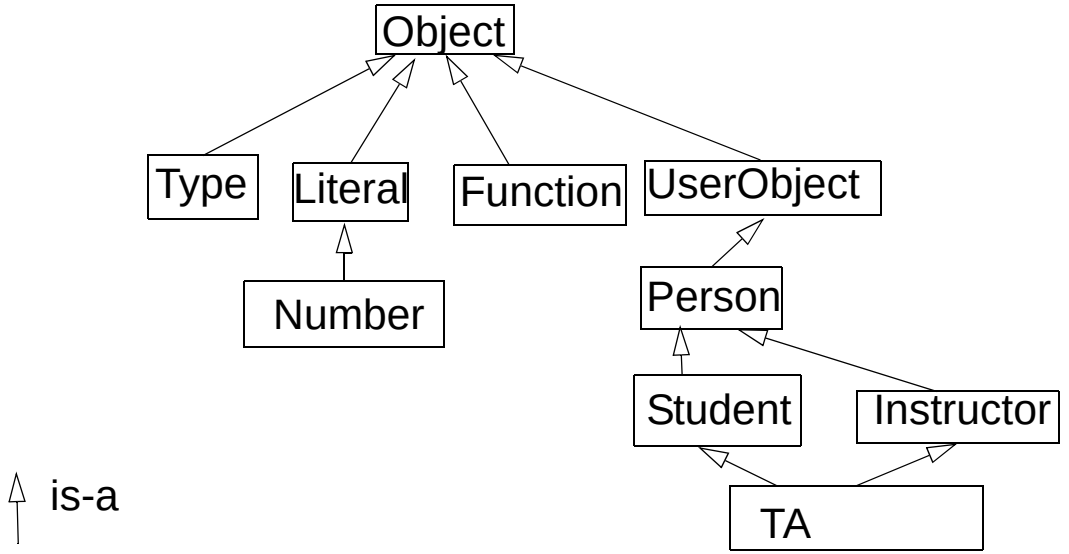
Amos II Data Model, Types

- For example:

```
create type Person;
create type Student under Person;
create type Instructor under Person;
create type TA under Student, Instructor;
create type Dept;
create type Course;
```

- Part of type hierarchy



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Amos II Data Model, Objects

- AmosQL Example:

  ```
  create Person instances :tore;
  ```

- creates new object, say `OID[1145]`, and binds *temporary* environment variable `:tore` to it. Environment variables disappear when transaction finished.
- The *DBMS manages* the objects.
- *Surrogate type* objects have unique *object identifiers* (OIDs), e.g. `OID[1145]`

  Explicit creation and deletion, e.g.

  ```
  delete :tore;
  ```

- Objects belong to one or more *types* where one type is *the most specific type*
- Regard database as *collection of objects*
- Built-in atomic types, *literals:* String, Integer, Real, Boolean, Date, e.g.

  ```
  'This is a string', 2.34, |2008-10-13/18:11:43|
  ```

- *Collection* types:

  Bag, e.g. `bag("Tore","Kjell","Thanh")`

  Vector, e.g. `{1,2,3}`

  Record, e.g. {"Name":"Tore", "Dept":"IT"}

  Tuple, e.g. ("Tore","IT")

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Amos II Data Model, Types

- *Classification* of objects:
- Every object is an instance of *at least one type*
- Objects are grouped by the types to which they belong (are instances of)
- Organized in type/subtype Directed Acyclic Graph
- Defines that OIDs of one type is *subset* of OIDs of other types
- *Type set* is associated with each OID
- Each OID has one *most specific type*
- *Multiple inheritance* supported
- Each surrogate type has an *extent* which is the set of objects having that type in its type set.
- Objects of user-defined types are instances of type Type and subtypes of UserObject
- Types and functions are objects too

  Of types ‘Type’ and ‘Function’

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Amos II Data Model, Functions

Examples of function *definitions*:

```
create function name (Person p) -> Charstring nm
    as stored;
create function name (Dept) -> Charstring as stored;
create function name(Course) -> Charstring as stored;
create function dept(Person) -> Dept as stored;
create function teacher(Course) -> Instructor
    as stored;
create function teaches(Instructor i)-> Bag of Course c
    as /* Inverse of teacher */
      select c where teacher(c)= i;
create function instructorNamed(Charstring nm)
                               ->  Instructor p
    as select p where name(p) = nm;
```

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Populate and query the database

- ```
  create Dept(name) instances :it ('IT');
  create Instructor(name, dept) instances
     :tr ('Tore', :it),
     :ko ('Kjell',:it);
  create Course(name,teacher) instances
  ('Databases',:tr), ('Data Mining',:ko), ('ETrade',:ko);
  ```
  Equivalent formulation using update command *set*:
  ```
  create Instructor instances :tr, :ko;
  set name(:tr) = 'Tore';
  set dept(:tr) = :it;
  set name(:ko) = 'Kjell';
  set dept(:ko) = :it;
  etc.
  ```
- Examples of functional *expressions*, the simplest *queries*:

```
sqrt(2)+3;
instructorNamed('Tore');
name(dept(instructorNamed('Tore')));
```
```

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Amos II Data Model, Functions

- Functions define *semantics* of objects (entities):
  - *Attributes* of objects, e.g. `name(Person)->Charstring`
  - *Relationships* among objects (mappings between arguments and results),
    ```
    parents(Person)->Bag of Person,
    dept(Person)-> Dept
    ```
  - *Views* on objects, derived function, e.g. `square, grandparents`.
  - *Procedural function* over objects
- Bag valued results allowed, e.g `Parents(...)->Bag of Person`
- Multiple argument allowed, e.g.
  ```
  1+2+3;
  children(Person x,Person u)-> Bag of Person
  ```
- Tuple values allowed, e.g.
  ```
  parents2(Person x) -> (Person m, Person f)
  ```

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Amos II Data Model, Functions

A function has two parts:

1. *Signature*:

- Name and types or arguments and results

```
name(Person p) -> Charstring n
teacher(Course c) -> Person
plus(Number x, Number y) ->Number r (infix '+')
children(Person m, Person f) -> Bag of Person c
parents2(Person p) -> (Person m, Person f)
```

2. *Body*:

- Specifies how to compute outputs from valid inputs.
- Usually *non-procedural* specifications, i.e. no side effects, *except* for *procedural functions*.

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Amos II Data Model, Functions

Four kinds of functions:

1. *Stored* functions (c.f. relational tables, object attributes, facts)

- Values stored explicitly in database, e.g. `name, parents`

2. *Derived* functions (c.f. relational views, object methods, rules)

- Defined as *queries* over other functions using AmosQL, e.g. `instructorNamed`
- Derived functions are immediately compiled and optimized by Amos II when defined

3. *Procedural functions* (c.f. SQL2003 UDFs, stored procedures, object methods)

- For procedural computations over the database

4. *Foreign* functions (c.f. object methods, built in predicates)

- Escape to programming language (Java, C, or Lisp), e.g. `plus, sqrt`
- E.g. foreign database access

Functions can also be *overloaded*:

- *Overloaded functions* have several different definition depending on the types of their arguments and results, e.g. `name(Person), name(Dept), 1+2, “a”+”b”`

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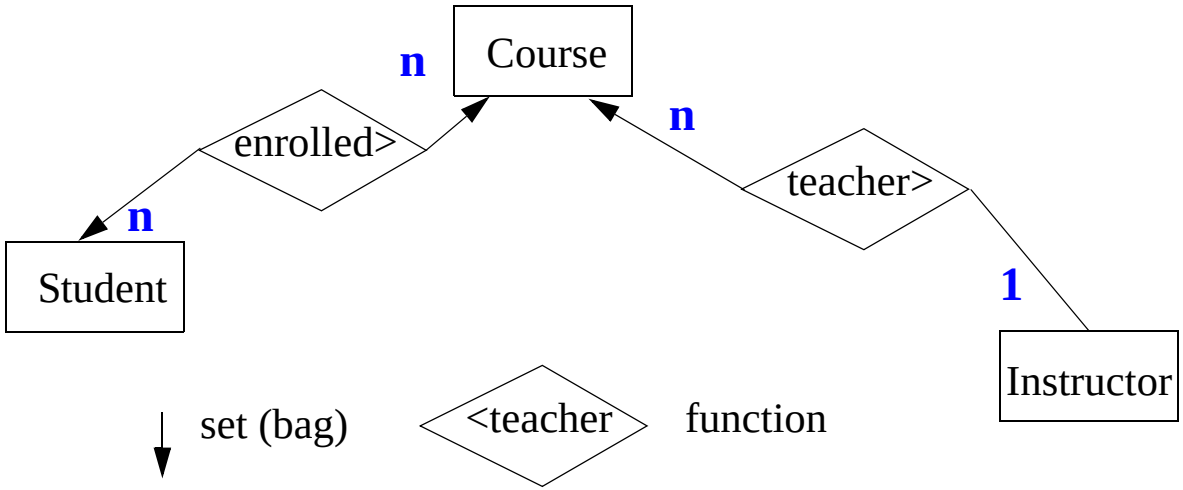
AmosQL language, Schema Definition

- Model E/R relationships with cardinality constraints as functions:

```
create function enrolled(Student e) -> Bag of Course c
as stored;

create function teacher(Course) -> Instructor as stored;
```



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AmosQL queries

Select statements

- Power: *Relationally complete* and more
- General format

  select <expressions>

  from <variable declarations>

  where <predicate>;
- Example:

```
select name(p), name(dept(p))
from Person p
where p = instructorNamed('Tore');
=>
("Tore","IT")
select p, name(p) from Person p;
=>
(#[OID 1440],"Tore")
(#[OID 1441],"Kjell")
(#[OID 1442],"Thanh")
```

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AmosQL queries

- Function composition simplifies queries that traverse function graph, *Daplex semantics*:

```
name(teaches(instructorNamed('Kjell')));
=>
"ETrade"
"Data Mining"
```

- *Daplex semantics*: `name` applied *on each element* in bag returned from `teaches`, a form of *path* specification over functions.

- Equivalent more SQLish *flattened query*:

```
select n
from Charstring n, Instructor i, Course c
where n = name(c) and
      c in teaches(i) and
      i = instructorNamed('Kjell');
```

Notice that literal types like `Charstring` can be used in `from` clause.

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AmosQL aggregate functions

- An *aggregate function* is a function that coerces some value to a single unit, a *bag*, before it is called.
- 'Bagged' arguments are not 'flattened' for aggregate functions (no Daplex semantics for aggregate functions).

```
count(teaches(instructorNamed('Kjell')));
=>
2
```

Signature of aggregate function count and sum:

count(Bag of Object) -> Integer

sum(Bag of Number) -> Number

- Nested queries, local bags:

```
sum(select count(teaches(p)) from Instructor p);
=>
3
```

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AmosQL quantification

Quantifiers

- *Existential and universal quantification* over subqueries supported through two aggregate functions:

  create function notany(Bag of Object) -> Boolean as foreign ...;

  create function some(Bag of Object) -> Boolean as foreign ...;

  some tests if there exists some element in the bag

  notany tests if there does not exist any element in the bag

- Example:

```
select name(p)
from instructor p
where notany(name(teaches(p))="Data Mining");
=> "Tore"
```

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Bag variables, Cursors

- Queries and function calls may return very large bags as results, for example:
  ```
  iota(1,1000000)+iota(1,1000000);
  ```
  returns 10^12 numbers!
- Can assign query result to *bag variable:*
  ```
  set :b = iota(1,1000000);
  count(:b);
  ```
  -> 1000000
- Can iterate over very large bags using *cursors*:
  ```
  open :c1 on iota(1,100000)+iota(1,100000);
  fetch :c1;
  ```
  -> 1
  ```
  fetch :c1;
  ```
  -> 2

  etc.

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Grouping

SQL's construct 'group by'of keysvalues is in AmosQL expressed using *second order* aggregate functions:

groupby(Bag of (Object, Object) q, Function aggfn) -> Bag of (Object g, Object a)

In subquery **q** returning bag of tuples (g, v) for each different value of **g** form the bag b_g of corresponding **v**:s and call the aggregate function aggfn(b_g). Return pair (g, aggfn(b_g)).

For example:

```
groupby((select name(i), c
         from Course c, Instructor i
         where teaches(i)=c),
        #'count');

=>

("K. Orsborn",2)
("T. Risch",1)
```

The notation `#'count'` denotes the function named *count*, a *functional constant*.

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Procedural functions

- E.g. to encapsulate database updates (constructors):

```
create function newInstructor(Charstring nm, Charstring dept) -> Instructor i as
as begin
    create Instructor instances i;
    set name(i)=nm;
    set dept(i)=dept;
    return i;
 end;
```

- Iterative update:

```
create function removeOverloadedInstructors(Integer th)->Bag of Charstring
  as for each Instructor i
    where count(select teaches(i)) >= th
    begin return name(i);
      delete i;
    end;
```

- *loop* and *while* statements as in PSM, if-then-else, cursors

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AmosQL sequences

Vectors (ordered sequences of objects)

- The datatype *vector* stores ordered sequences of objects of any type, e.g. numerical vectors, tuples.
- Vector declarations can be parameterized by declaring
  Vector of <type>
  e.g.

```
create type Segment;
create function start(Segment)->Vector of Real as stored;
create function stop(Segment)->Vector of Real as stored;
create type Polygon;
create function segments(Polygon)->Vector of Segment
   as stored;
```

- Vector values have system provided *constructors*:

```
create Segment instances :s1, :s2;
set start(:s1)={1.1,2.3};
set stop(:s1)={2.3,4.6};
set start(:s2)={2.3,4.6};
set stop(:s2)={2.8,5.3};

create Polygon instances :p1;
set segments(:p1)={:s1,:s2};
```

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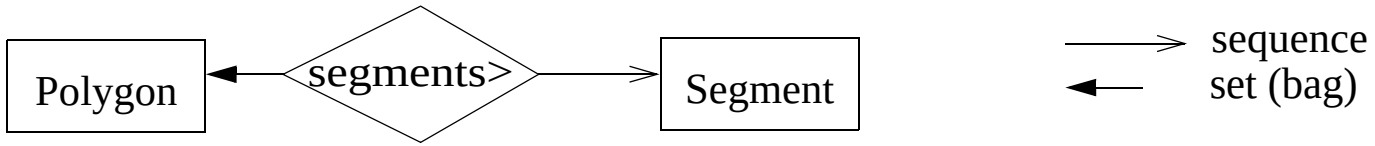
AmosQL sequences

Vector types can be used as other types.

- Functions on sequences can be defined

```
create function square(Number r)->Number as r * r;
create function length(Segment l)-> Real
  as euclid(start(l),stop(l));
create function length(Polygon p)->Real
as sum(select length(s)from Segment s where s in segments(p));
```

- Extented ER notation:



- Queries, e.g.:

```
length(:s1);
count(select s from Segment s where length(s)>1.34);
```

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AmosQL schema queries

Querying the schema

- System data is queryable as any other database data
- E.g. Find the names of the supertypes of TA:

```
name(supertypes(typenamed(“TA”)));
"STUDENT"
"INSTRUCTOR"
```

- Find the types of the first argument of a resolvent:

```
name(resolventtype(#'teaches'));
"INSTRUCTOR"
```

- Find all functions whose single argument have type INSTRUCTOR:

```
signature(methods(typenamed('Instructor')));
"TEACHES(INSTRUCTOR)->COURSE"
```

- Notice that the schema can be browsed by calling `goovi();` when Amos II combined with Java (javaamos.cmd).

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Amos II

How to run Amos II:

- Install system on your PC by downloading it from

  `http://user.it.uu.se/~udbl/amos/`

- User's Guide in

  `http://user.it.uu.se/~udbl/amos/doc/amos_users_guide.html`

- Amos II Tutorials:

  `http://user.it.uu.se/~torer/kurser/dbt/tutorial.amosql`

  `http://user.it.uu.se/~udbl/amos/doc/tut.pdf`

- These slides:

  `http://user.it.uu.se/~torer/kurser/dbt/amosQL.pdf`

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Summary

- AmosQL provides flexible Object-Relational DBMS capabilities
- Not hard wired object model, but dynamically extensible model
- Powerful object-orinented and functional data modeling
- Very good support for ad hoc queries
- Extensible query processor

The key is the f*unctional data model* of Amos II.