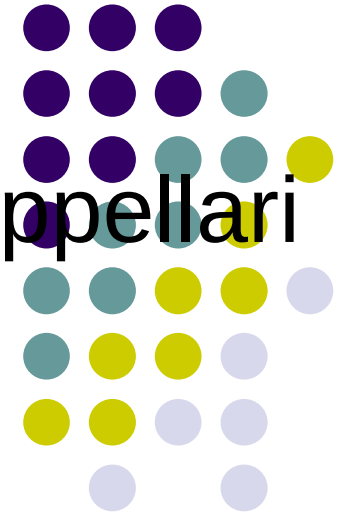
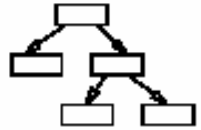
Object Relational

Paolo Cappellari

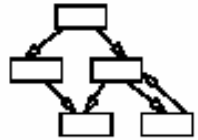


History of DB Models

- 1950 File Systems, Punched Cards



- 1960 Hierarchical
  (IMS IBM Mainframes)



- 1970 Network
  (CODASYL, IDMS)

- 1980 Relational
  (ORACLE, DB2, Sybase)

- 1990 Object-Oriented, Object-Relational
  (O2, ORACLE9i)

Relational Model

- Emergence of data model
- Data independence
- High-level approach
- Standardization

- Built-in data types
- Little abstraction
- Separation between data and operations

Object-Oriented Model

- Complex application datatypes
- Object Abstraction
- Encapsulation of behavior
- High performance for specific application

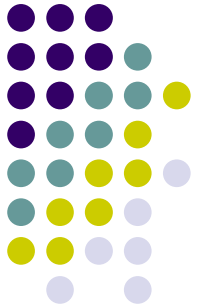
- No backwards compatibility
- Closely tied to language and application

Object-Relational Model

- Synthesis of two worlds
- Upward compatibility
- Robustness of mature systems

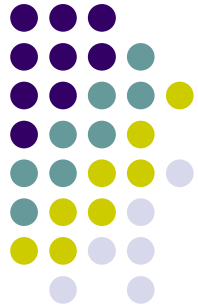
- Hybrid approach
- Legacy problems

Evolution of DBMS's



- Object-oriented DBMS's failed because they did not offer the efficiencies of well-entrenched relational DBMS's.
- Object-relational extensions to relational DBMS's capture much of the advantages of OO, yet retain the relation as the fundamental abstraction.

Main Features



Relation is still the fundamental abstraction, with integration of OO features

- Structured Types

  Non-atomic types

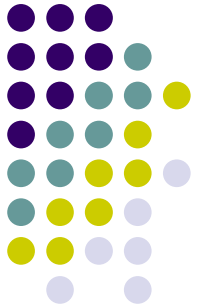
- Methods

  Special operations can be defined for a type

- References

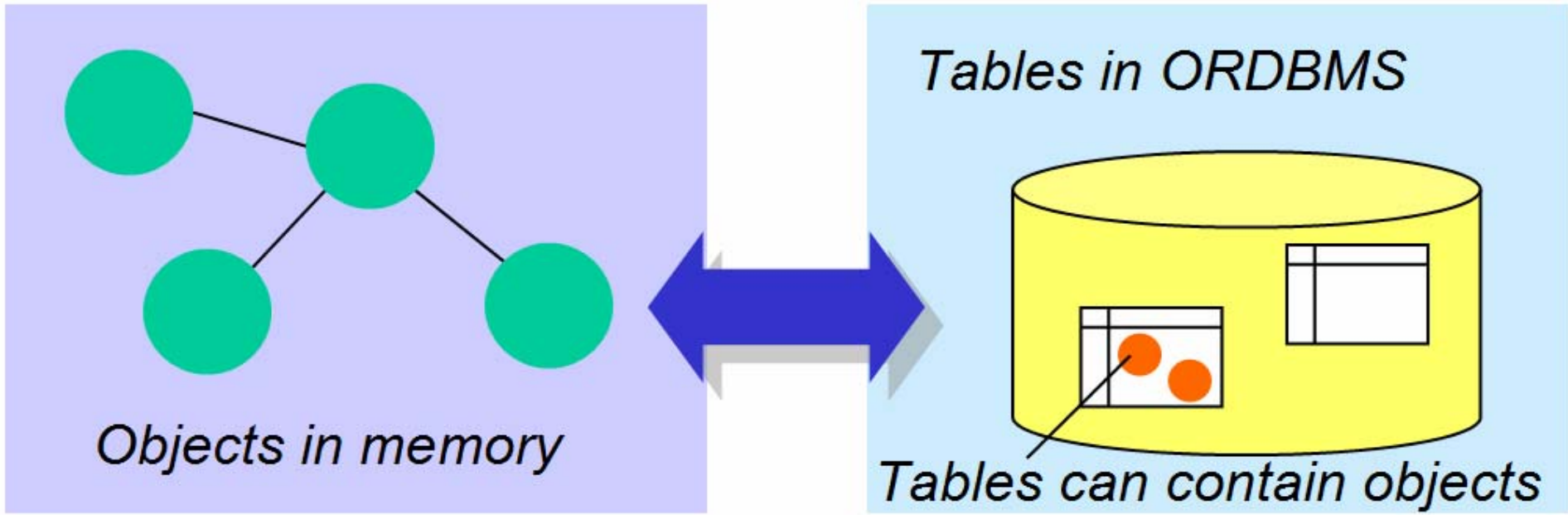
  Pointers to tuples

Object Orientation

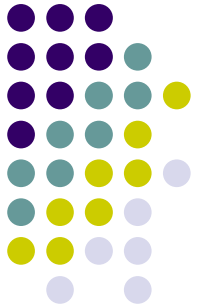


- Abstract data types
  - defining classes with data structure and operation on them whose details are hidden
- Object Identity
  - every entity is uniquely identifiable
- Polymorphism and overloading
  - to distinguish between two or more operation having the same name that have different semantics or that operate on values of different types
- Inheritance
  - share structure and behavior among related types

OO – OR Mapping

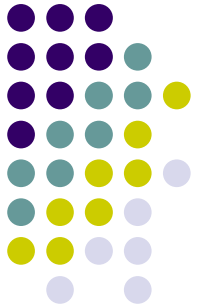


Structured Types– SQL99



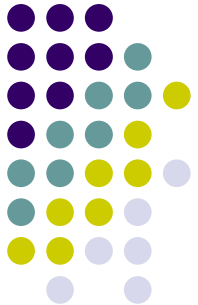
- UDT – User Defined Type
  - A UDT can be the type of a table
  - A UDT can be the type of an attribute belonging to some table
  - A UDT can inherit from another UDT

Three kinds of UDTs



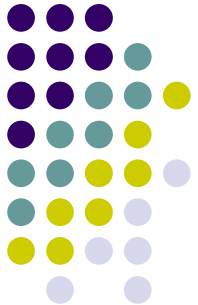
- Distinct types
- Structured UDTs as values
- Structured UDTs as objects

Distinct types



```
CREATE TYPE shoe_size AS INTEGER FINAL
CREATE TYPE iq AS INTEGER FINAL

CREATE TABLE demograph_people (
    name                CHARACTER VARYING (50),
    footsies            shoe_size,
    smarts              iq,
    last_purchase       DECIMAL(5,2)      )
```

Distinct types



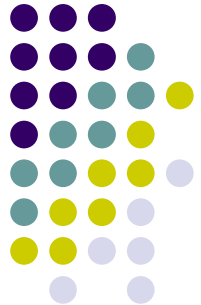
- Incorrect use of distinct types

```
SELECT name
FROM demograph_people
WHERE footsies > smart
```

- Correct use: CAST

```
...
WHERE
        CAST (footsies TO INTEGER)
        >
        CAST (smarts TO INTEGER)
```

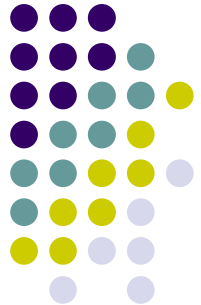
Distinct types (DB2)



CREATE **DISTINCT** TYPE shoe_size AS INTEGER
WITH COMPARISONS

- Keyword DISTINCT is required
- Generates functions to cast between the distinct type and its source type
- WITH COMPARISONS is required for almost all base types and generates support for the comparison operators (=, <>, <, <=, >, >=).

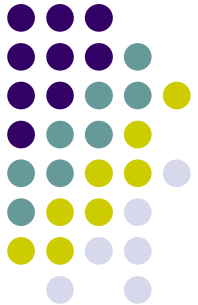
Structured UDTs as values



- Address
  - Number, street_name, apartment_number, city, state, postal_code
- Movie
  - Title, length, description, …

- Can be used as first-class type
- Can have functions associated
  - Comparison (*equals)* function, …

Create type syntax



CREATE type-name

AS *representation*

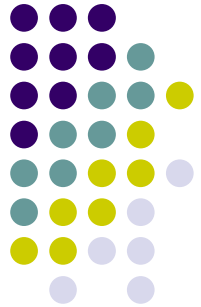
[[NOT] INSTANTIABLE]

[[NOT] FINAL]

[*reference-type-specification*]

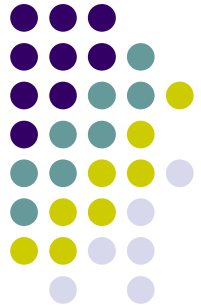
[*method-specification-list*]

Type definition



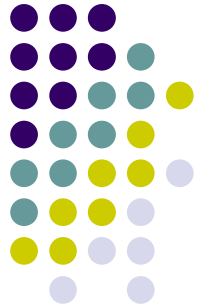
```
CREATE TYPE addressLongT AS (
Number                  CHARACTER(6),
Street                  ROW (
    street_name                 CHARACTER VARYING(35),
    street_type                 CHARACTER VARYING (10)
                                        DEFAULT ‘Street’        ),
City                    CHARACTER VARYING (35),
State                   CHARACTER(2) NOT NULL,
Zip_code                ROW (
    base                        CHARACTER(5),
    plus4                       CHARACTER(4)    )       )
NOT FINAL
```

Type definition (DB2)



```
CREATE TYPE addressT AS (
Number      CHARACTER(6),
City        CHARACTER VARYING(35),
State       CHARACTER(2) )
NOT FINAL
MODE DB2SQL
WITH FUNCTION ACCESS
REF USING INTEGER
```

Type definition (DB2)



CREATE TYPE PersonT AS (

name VARCHAR(50),

address **addressT**)

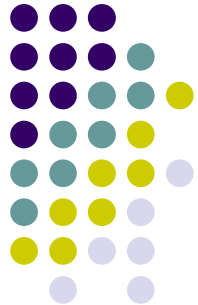
NOT FINAL

MODE DB2SQL

WITH FUNCTION ACCESS

REF USING INTEGER

Type definition (DB2)



CREATE TYPE PersonT AS (

name VARCHAR(50),

address **REF(addressT)**)

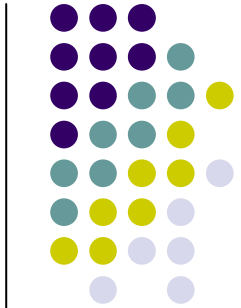
NOT FINAL

MODE DB2SQL

WITH FUNCTION ACCESS

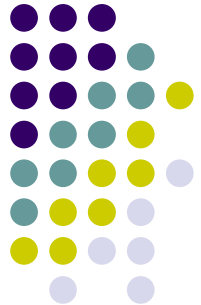
REF USING INTEGER

Type definition (DB2)



```
CREATE TYPE addressT AS (
Number CHARACTER(6),
City       CHARACTER VARYING(35),
State      CHARACTER(2) )
NOT FINAL
MODE DB2SQL
WITH FUNCTION ACCESS
REF USING INTEGER
    METHOD DISTANCE (addressT)
    RETURNS FLOAT
    LANGUAGE JAVA
    PARAMETER STYLE DB2GENERAL   -- to be used with structured and JAVA
    NO SQL                       -- no SQL statement allowed in method
```

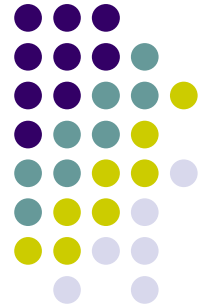
Accessing attributes



- Suppose to have a relation customer (c) with a column (cust_addr) defined of type *addressLongT*
- c.cust_addr.number
- c.cust_addr.zip_code.base
- c.cust_addr[2].zip_code.base

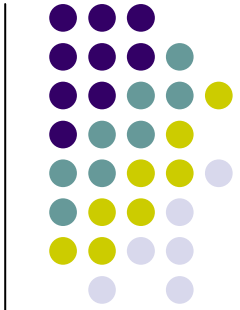
- Columns can be defined as ROW and also as ARRAY.

Accessing attributes (DB2)



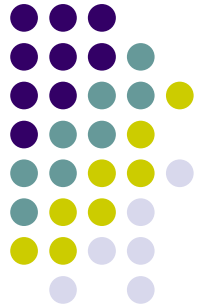
- Suppose to have a relation customer (c) with a column (cust_addr) defined of type *addressLongT*
- c.cust_addr..number
- c.cust_addr..zip_code..base
- c.cust_addr[2]..zip_code..base

Accessing attributes (DB2)



```
CREATE FUNCTION addrT_transform (
                                        addr addressT)
RETURNS VARCHAR(100) LANGUAGE SQL
RETURN
   addr..number || ', ' || addr..city || ', ' || addr..state

CREATE TRANSFORM FOR addressT
   DB2_PROGRAM (
   FROM SQL WITH FUNCTION addrT_transform )
```

Accessing attributes

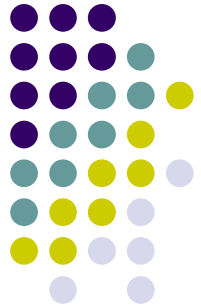


- Use the alias (or correlation) name to avoid ambiguities:

```
SELECT
        customers.name,
        customers.cust_addr.street_name
FROM
        customers, customers.cust_addr
```

- Should the expression *cust_addr.street_name* be resolved as *schema.table.column* or *table.column.attribute*?

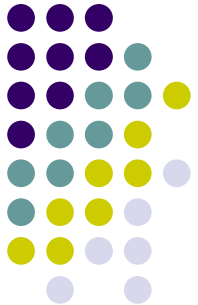
Accessing attributes



- Use the correlation name to avoid ambiguities:

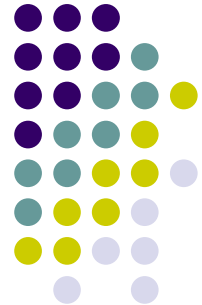
```
SELECT
        c.name,
        c.cust_addr.street_name
FROM
        customers AS c
```

Observer and Mutators



- Allow to access, set and retrive, the attributes of UDTs.
- They are methods that the system automativcally provides.

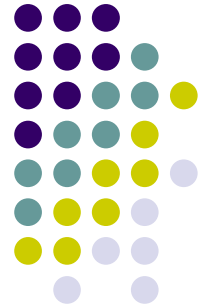
Observer and Mutators



SELECT movie.runs FROM movie_table WHERE title = ‘Star Wars’	SELECT movie.runs() FROM movie_table WHERE title = ‘Star Wars’

UPDATE movie_table SET movie.runs = 113 WHERE title = ‘Star Wars’	UPDATE movie_table SET movie = movie.runs(113) WHERE title = ‘Star Wars’

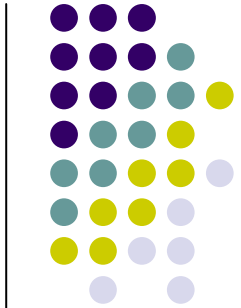
Observer and Mutators



SELECT movie..runs FROM movie_table WHERE title = ‘Star Wars’	SELECT movie..runs() FROM movie_table WHERE title = ‘Star Wars’

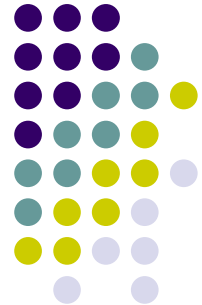
UPDATE movie_table SET movie..runs = 113 WHERE title = ‘Star Wars’	UPDATE movie_table SET movie = movie..runs(113) WHERE title = ‘Star Wars’

Method definition



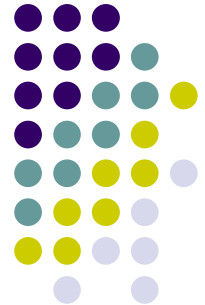
- Methods are defined in two ways and in two places, and both are required
  - Define the signature among the type definition
  - Define the implementation

Method definition



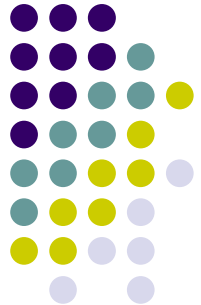
```
CREATE TYPE movieT AS (
   title            CHARACTER VARYING (100),
   description      CHARACTER VARYING (500),
   runs             INTEGER )
NOT FINAL
METHOD length_interval ( )
   RETURNS INTERVAL HOUR(2) TO MINUTE
```

Method definition



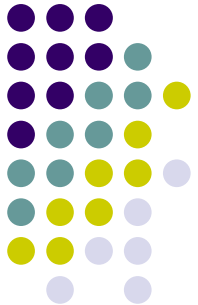
```
CREATE INSTANCE METHOD
   length_interval ( )
RETURNS INTERVAL HOUR(2) TO MINUTE
FOR movie
/*
   implementation
*/
RETURN …
```

Method invocation



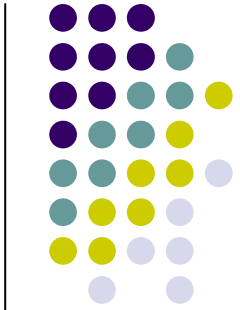
```
CREATE TABLE movie_table (
    stock_number            CHARACTET(8),
    movie_info              movieT,
    rental_quantity         INTEGER,
    rental_cost             DECIMAL(5,2)      )

SELECT mt.movie_info.length_interval
FROM movie_table AS mt
WHERE mt.movie_info.title = ‘Star Wars’
```

Method definition (DB2)



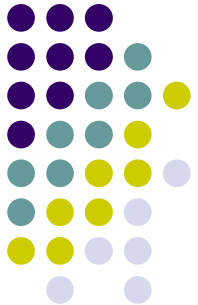
```
CREATE TYPE addressT AS (
Number          CHARACTER(6),
City     CHARACTER VARYING(35),
State    CHARACTER(2) )
NOT FINAL
MODE DB2SQL
WITH FUNCTION ACCESS
REF USING INTEGER
    METHOD SAMECITY (addr addressT)
    RETURNS INTEGER
    LANGUAGE SQL
```

Method definition (DB2)



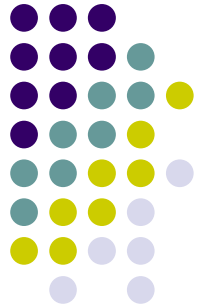
```
CREATE METHOD SAMECITY (addr addressT)
RETURNS INTEGER
FOR addressT
RETURN (
    CASE WHEN (self..city = addr..city)
    THEN 1
    ELSE 0
END)
```

Constructors



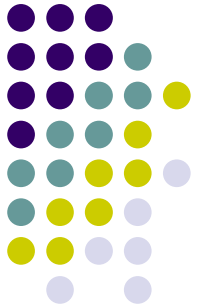
- Each defined UDT has a constructir
- The system automatically provides for a *niladic* constructor
- Users usually need for more sophisticated constructors
- Constructors method are marked with the keyword CONSTRUCTOR in the method definition

Constructor definition



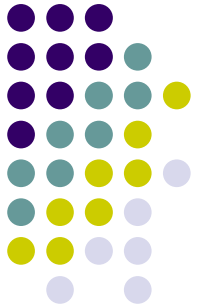
```
CREATE CONSTRUCTOR METHOD movieT (
    name CHARACTER VARYING(100),
    descr CHARACTER VARYING(500),
    length INTEGER )
RETURNS movieT
BEGIN
    SET SELF.title = name;
    SET SELF.description = descr;
    SET SELF. runs = length;
    RETURN SELF;
END
```

Constructor definition (DB2)



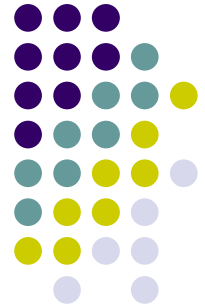
```
CREATE function addressT (
    num          CHARACTER(6),
    cit          CHARACTER VARYING(35),
    sta          CHARACTER(2) )
RETURNS addressT
RETURN addressT()..number(num)..city(cit)..state(sta)
```

Storing in the database



```
INSERT INTO movie_table VALUES (
    ‘152208-A’,         -- stock-number
    NEW movieT(
          ‘Star Wars’,
          ‘Action-Fantasy. Part IV in a George    Lucas
           epic, Star Wars: …  ’
          125    ),        -- new MOVIE instance
    23,                    -- rental-quantity in stock
    2.99          )        -- rental-cost
```

Storing in the database (DB2)



INSERT INTO movie_table VALUES (

‘152208-A’, -- stock-number

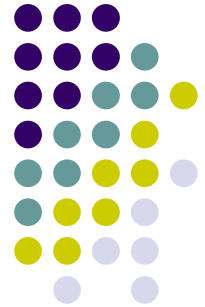
movieT()**..title**(‘Star Wars’)**..description**(‘Action-Fantasy. Part IV in a George Lucas epic, Star Wars: … ’)**..runs**(125)),

-- new MOVIE instance

23, -- rental-quantity in stock

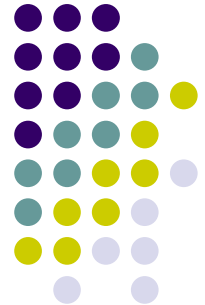
2.99) -- rental-cost

Storing in the database (DB2)



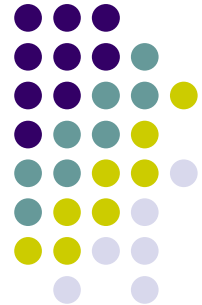
```
INSERT INTO movie_table VALUES (
    '152208-A',          -- stock-number
    movieT(
        'Star Wars',
        'Action-Fantasy. Part IV in a George    Lucas
         epic, Star Wars: …  '
        125    ),        -- new MOVIE instance using the
                         -- constructor function
    23,                  -- rental-quantity in stock
    2.99         )       -- rental-cost
```

Structured UDTs as objects



- Define a special sort of table (typed table or table of type) to represents instances of a type.
- Each instance is unique and has its own indenty.
  - Each instance behaves exactly as an object
- Each row stored in the table is an instance, or a value, of the associated structured UDT.

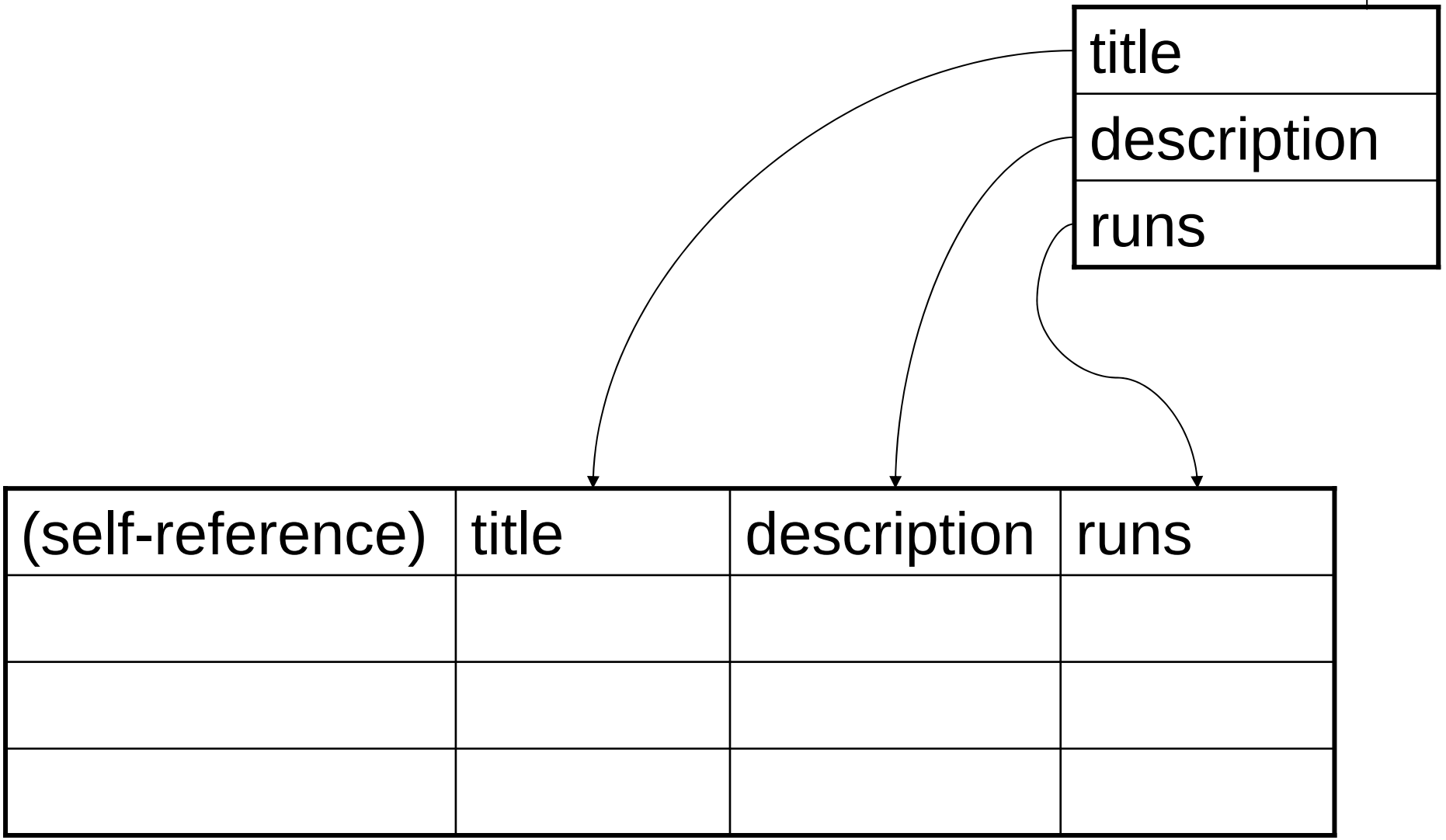
Typed tables



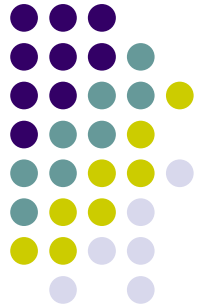
- The typed table has a column for each attributes in the UDT associated, plus an *object-identifier* known as *Self-referencing column*.

```
CREATE TABLE movie_TypedTable OF movie
    REF IS oidName SYSTEM GENERATED
```

Typed tables



self-reference specification



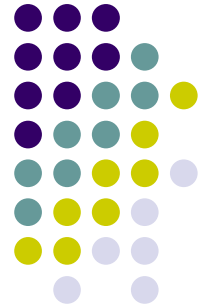
- In the type definition the reference type has to be specified:

  CREATE TYPE movieT AS (*attributes*)

  NOT FINAL

  <*reference-type specification*>

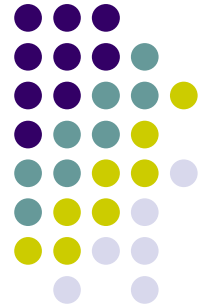
Types of *self-reference specification*



- <*reference-type specification*> can be:
  - System-generated ::= REF IS SYSTEM GENERATED
  - User-defined ::= REF USING <*predefined SQL type*>
  - Derived ::= REF FROM <*attribute-list from the structured type*>

- When defining a typed table, the <*reference-type specification*> must be specified again(redundantly), associating it with a name (the name of the *self-referencing* column).

Values for *self-reference*

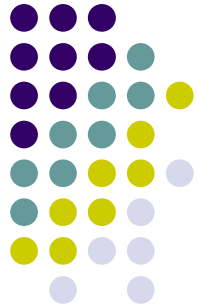


- REF IS <*selfColumnName*>
  - SYSTEM GENERATED: generated by the system.
  - USER GENERATED: it is responsability of the application to choose the values stored in each row of the column.
  - DERIVED: the system uses the values in the specified columns (in the type definition) to derive the reference value. The columns should be under a PRIMARY KEY or a UNIQUE constraint.

References

```
CREATE TYPE movieT AS (
    title           CHARACTER VARYING (100),
    description     CHARACTER VARYING (500),
    runs            INTEGER )
INSTANTIABLE
NOT FINAL
REF IS SYSTEM GENERATED

CREATE TYPE playerT AS (
    name            CHARACTER VARYING (35)
    role            CHARACTER VARYING (35) )
    film            REF (movieT) )
NOT FINAL
REF IS FROM (name, role, film)
```

References



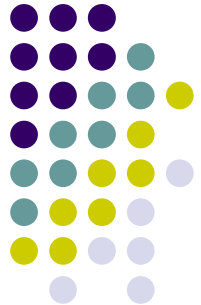
```
CREATE TABLE movies OF movieT
title WITH OPTION CONSTRAINT NOT NULL,
REF IS oidMovie SYSTEM GENERATED

CREATE TABLE actors OF playerT
PRIMARY KEY (name, role, film),
film WITH OPTION SCOPE movies,
REF IS oidActor DERIVED
```

References

Actors			
oidActor	Name	Role	Film
???	Hamill	Skywalker	???
???	Ross	Ross	???

movies			
oidMovie	Title	Description	Runs
???	Star Wars	Fantasy	100
???	Final Fantasy	Fantasy	112

Following the reference



- Retrive values:

SELECT film -> runs

FROM actors

WHERE name = ‘Hamill’ and role = ‘Skywalker’

- The statement retrives a value from the movies table without specifing that table in the FROM clause. The

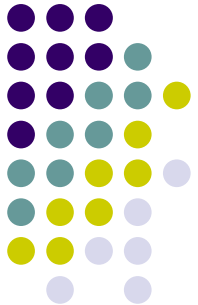
- Retrive structured type instance:

SELECT DEREF (film)

FROM actors

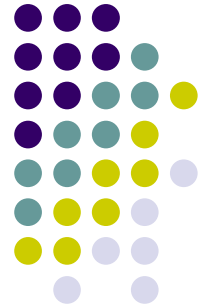
WHERE name = ‘Hamill’ and role = ‘Skywalker’

Typed table (DB2)



```
create table Address of addressT (
    ref is oidAddress system generated,
    number  WITH OPTIONS NOT NULL,
    state       WITH OPTIONS NOT NULL,
    CONSTRAINT pk PRIMARY KEY (
        number, state)  )
```

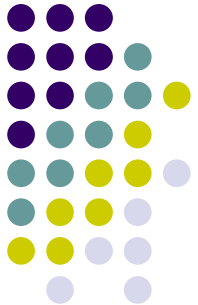
Typed table (DB2)



```
CREATE TYPE addressT AS (
    street      varchar(50),
    city        varchar(50),
    zip         varchar(4) )
NOT FINAL
INSTANTIABLE
MODE DB2SQL
WITH FUNCTION ACCESS
REF USING INTEGER
```

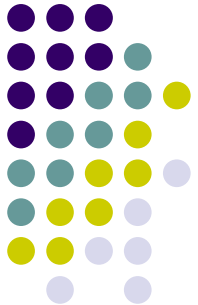
```
CREATE TYPE personT AS (
    name        varchar(50),
    age         varchar(50),
    address     REF(addressT)
        )
NOT FINAL
INSTANTIABLE
MODE DB2SQL
WITH FUNCTION ACCESS
REF USING INTEGER
```

Typed table (DB2)



```
create table Address of addressT (
ref is oidAddress system generated,
street WITH OPTIONS NOT NULL,
city WITH OPTIONS NOT NULL,
CONSTRAINT pkAddress PRIMARY KEY (street, city)  )

create table Person of personT (
ref is oidPerson system generated,
name WITH OPTIONS NOT NULL,
age WITH OPTIONS NOT NULL,
CONSTRAINT pkPerson PRIMARY KEY (name, age),
address WITH OPTIONS SCOPE Address)
```

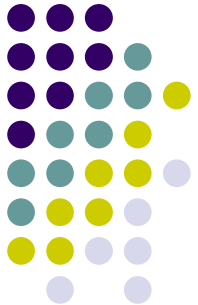
Typed table (DB2)



```
create table Address of addressT (
ref is oidAddress system generated,
street WITH OPTIONS NOT NULL,
city WITH OPTIONS NOT NULL,
CONSTRAINT pk PRIMARY KEY (street, city)  )
```

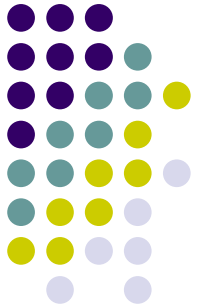
```
create table X (a varchar(50) NOT NULL, b varchar(50), c
    varchar(50), d varchar(50), e varchar(50),
PRIMARY KEY (a),
FOREIGN KEY (b,c) REFERENCES Person (name, age),
FOREIGN KEY (d,e) REFERENCES Address (street, city) )
```

Insert into typed table (DB2)



```
insert into Address values
   (AddressT(5),'a','b','c');

insert into Person values
   (PersonT(5),'nome','eta',AddressT(5));
```

Following references DB2

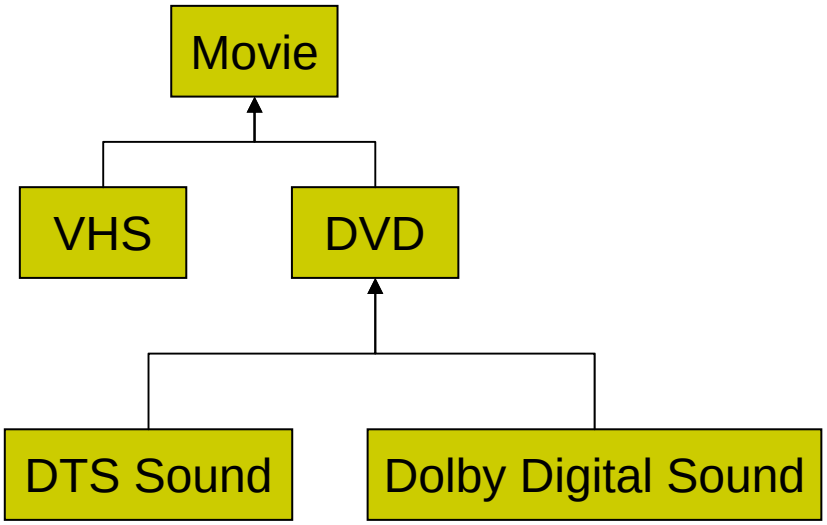


select name, address->city, address->zip
from Person

- No mention to the Address table!

Inheritance

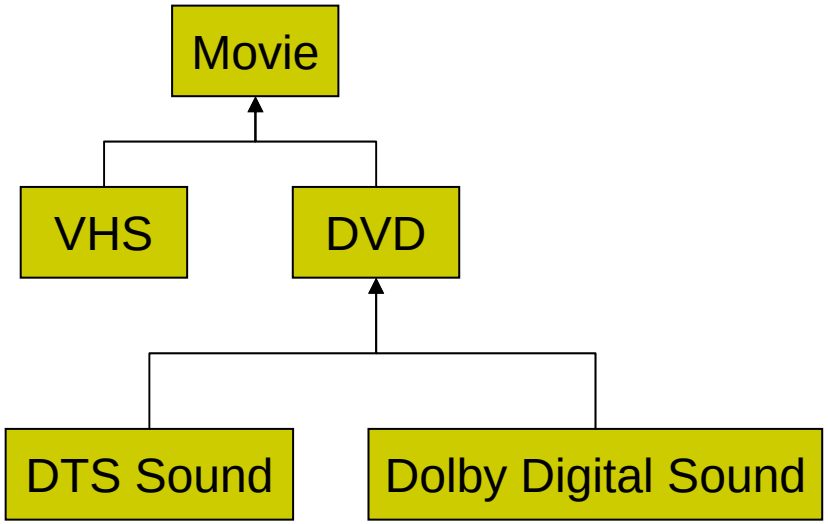
- A type hierarchy in SQL is a collection of UDTs.



Inheritance on types

- Super-type definition

```
CREATE TYPE movieT AS (
    title           CHARACTER VARYING (100),
    description     CHARACTER VARYING (500),
    runs            INTEGER )
NOT INSTANTIABLE
NOT FINAL
```



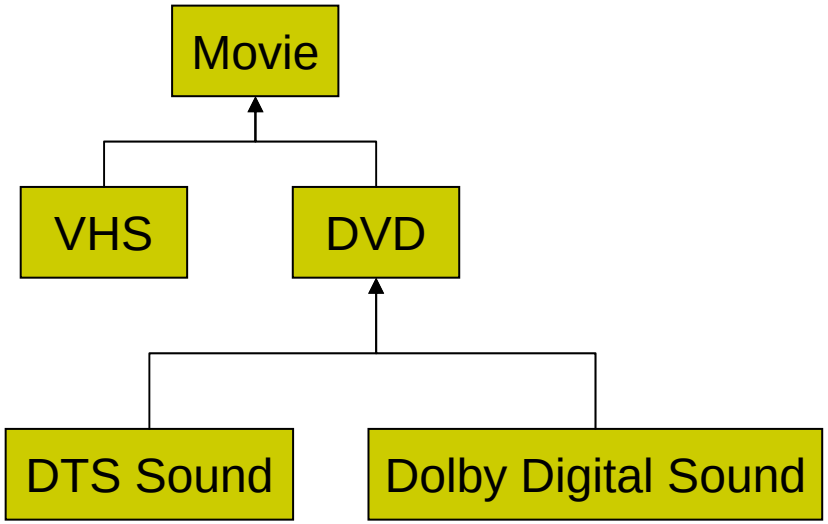
Inheritance on types

- Sub-type definition

```
CREATE TYPE dvdT UNDER movieT AS (
   stock-number INTEGER,
   rental_price    DECIMAL(5,2),
   extra_feature  feature_desc ARRAY[10] )
```

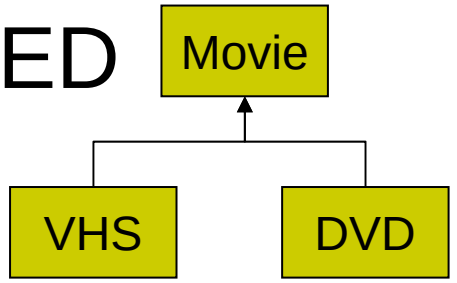
INSTANTIABLE

NOT FINAL

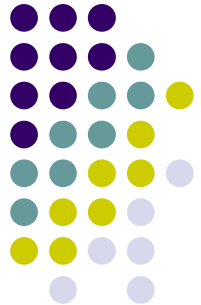


Inheritance on typed-tables

```
CREATE TABLE short_movies OF movieT
REF IS oidMovie SYSTEM GENERATED,
runs WITH OPTION CONSTRAINT smc_runs
   CHECK (runs < 90)

CREATE TABLE short_dvd OF dvdT
UNDER short_movies
REF IS oidDvd SYSTEM GENERATED
```



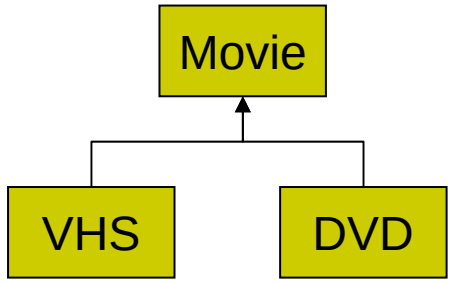
Retrieval in hierarchies



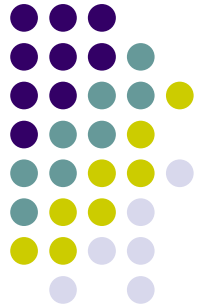
- The query:

```
SELECT titles, runs
FROM short_movies
WHERE runs < 60
```

- Retrives title and runs from short_movies tables, then retrives title and runs from short_dvd table!



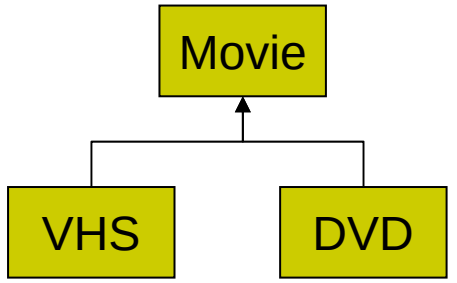
Retrieval in hierarchies



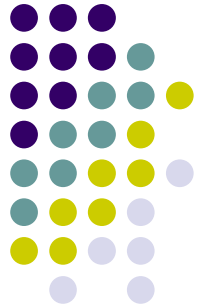
- The query:

```
SELECT titles, runs
FROM ONLY (short_movies)
WHERE runs < 60
```

- Retrives title and runs from short_movies that are ***not*** available on dvd (and on VHS).



The type predicate

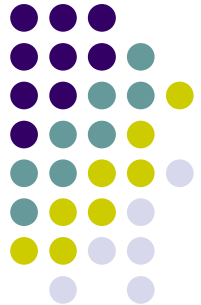


- Allows to determine the type of a structured type instance.

```
SELECT name, title
FROM actors
WHERE film IS OF (dvd)
```

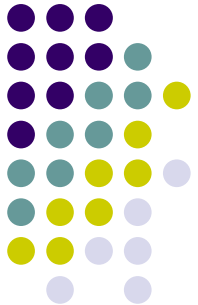
- WHERE film IS NOT OF (dvd)
- WHERE film IS OF (ONLY dvd)

The hierarchy model



- There are several mental models to represent relationships between the tables in a table hierarchy and the rows in those tables.
  - Duplicate-row model
  - Single-table model
  - Union model

Duplicate-row model



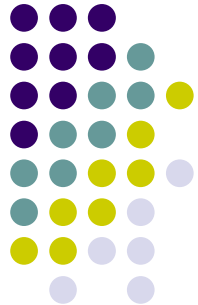
movie table

Rocky Horror	Description 1	100
Dr. Stangelove	Description 2	93
Star Wars	Description 3	90
Wizards	Description 4	82

dvd table

Dr. Stangelove	Description 2	93	DR846	2.49
Star Wars	Description 3	90	SF933	4.99

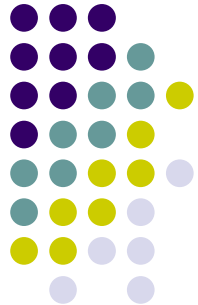
Single-table model



movie + dvd table

movie	Rocky Horror	Description 1	100		
DVD	Dr. Stangelove	Description 2	93	DR846	2.49
DVD	Star Wars	Description 3	90	SF933	4.99
movie	Wizards	Description 4	82		

Union model



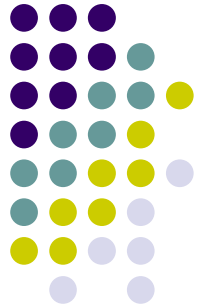
movie table

Rocky Horror	Description 1	100
Star Wars	Description 3	90

dvd table

Dr. Stangelove	Description 2	93	DR846	2.49
Star Wars	Description 3	90	SF933	4.99

Hierarchies in DB2



- Conform to the standard!

FINE