

# IACDM

## Data Integration – Exercise Class 1

The logo for Cartagena99 features the text 'Cartagena99' in a stylized, teal-colored font. The '99' is significantly larger and more prominent than the rest of the text. The logo is set against a background of overlapping light blue and orange shapes that resemble a stylized map or a graphic element.

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# Data Integration

- *The aim of a **DIS** (Data Integration System) is to set up a system where it is possible to **query different data sources as they were a unique one**, through a **global schema**.*
- *To our aims, **two** types of **data integration**:*
  - ***Homogeneous data sources** → all the data sources use the same data model (e.g., all relational)*
  - ***Heterogeneous data sources** → different data models (e.g., one relational database to be integrated with an XML document)*

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# Phases of the integration of homogeneous data sources

## 1. Source schema reverse engineering

## 2. Schema integration

- a. Related concept identification + Conflict analysis and resolution
- b. Global conceptual schema
- c. Conceptual to logical translation of the global schema

## 3. (GAV) Mapping definition and query answering

- a. GAV Mapping definition
- b. Query formulation [*on the global schema*]
- c. Query rewriting

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# Source schema reverse engineering

- **Given the logical schema** – that may also be not relational –, **find the ER schema**

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# Schema integration

- Related **concept identification + Conflict analysis and resolution**  
*(In this phase we draw a table putting in correspondence the different concepts in the different sources, and we decide how to solve the possible conflicts)*
- **Global conceptual schema**  
*(Here we produce the Entity-Relationship global schema, solving the conflicts as we have decided in the previous phase)*
- **Conceptual to logical translation** of the global schema  
*(In our exercises, we always use the relational model)*

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# (GAV) Mapping definition and query answering

## GAV Mapping definition

- **GAV Mapping** definition  
*(Define the relations of the global schema as views on the sources)*
- **Query formulation** *[on the global schema]*
- **Query rewriting**  
*(In this phase the queries are rewritten in terms of the views using the mappings)*  
*[Note that usually in the exercises we will start with the query on the global schema, because the exercises usually ask to define the GAV mappings just for the tables involved in the query answer.]*

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# Conflicts

## Types of conflicts:

- **Name conflicts** (*i.e., synonymies and homonimies: e.g., client vs customer*)
- **Type conflicts** (*In parentheses because usually we do not consider them in our exercises. For example, if an identifier is a string in one case and an integer in another case*)
- **Data semantics** (*E.g., different currencies or unit of measure*)
- **Structure conflicts** (*E.g., a concept is an attribute in a source and an entity in another one*)
- **Cardinality conflicts** (*E.g., a movie may have just one director in a source, while another source allows more directors*)

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# Exercise

**LALuxuryHouses** is a real estate agency located in **Los Angeles** and its business is **exclusively focused** on **luxury villas** located in the Los Angeles area (State of California).

Differently, **USAHouses** is an important real estate agency that **rents** and **sells houses** in all the main states of the USA.

**USAHouses** wants to **increase** its **business** in **Los Angeles**. Since the Los Angeles area is currently only partially covered by the agencies of USAHouses, its management decided to **buy LALuxuryHouses** and founded a **new company** called **USARealEstateCompany**. The management of USARealEstateCompany (the new company) wants to **integrate** the **information** available in the **two sources**

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# LA LuxuryHouses

CLIENTS (SSN, Lastname, Firstname, Address, City, State, Age, PhoneNumber)

EMPLOYEE (IDEmployee, Lastname, Firstname, PhoneNumber)

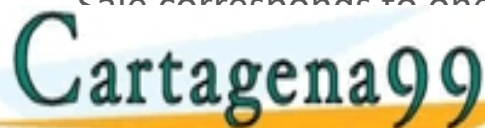
HOUSES (HouseAddress, HouseCity, SizeSquareMeters, Rooms) // The size of each home is measured in square meters.

HOUSE-OWNEDBY (HouseAddress, HouseCity, ClientSSN) // Table House-OwnedBy is used to store the information about the owners of each house.

RENTAL-CONTRACT (IDRentContract, HouseAddress, HouseCity, StartDate, EndDate, AnnualCost, IDEmployee) // Each tuple in Table Rental-Contract represents the rental of a house (identified by the pair HouseAddress, HouseCity) for the period from StartDate to EndDate

RENTEDBY (IDRentContract, ClientSSN) // Table RentedBy is used to store who are the clients associated to each rental contract (i.e., who rented the house associated to the contract).

SALE (IDSaleContract, HouseAddress, HouseCity, Date, Cost, IDEmployee) // Each tuple in Sale corresponds to one sale.

The logo for Cartagena99 features the word "Cartagena" in a blue, serif font and "99" in a larger, bold, blue font. Below the text is a stylized orange and yellow swoosh that resembles a sun or a wave.

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# USAHouses

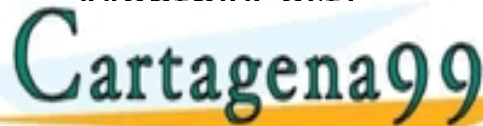
BUYERS (BuyerID, Name, Surname, Address, City, State, YearOfBirth, SSN, PhoneNumber) // Each tuple in Table Buyers represents someone who bought or rented a real estate

OWNERS (OwnerID, Name, Surname, Address, City, State, YearOfBirth, SSN, PhoneNumber) // Each tuple in Table Owners represents someone who owns a real estate

AGENTS (AgentID, Name, Surname, MobilePhoneNumber, OfficePhoneNumber)

REALESTATES (IDRE, Address, City, State, NumOfRooms, Size\_SquareFeet, NumberOfFloors, OwnerID) // The size of each real estate is measured in square feet.

REALESTATE-RENTAL (IDRE, StartDate, EndDate, BuyerID, AgentID, MonthlyCost)

The logo for Cartagena99 features the text 'Cartagena99' in a stylized, green, sans-serif font. The '99' is significantly larger and more prominent than the 'Cartagena' part. The text is set against a light blue and white background with a subtle wave-like pattern.

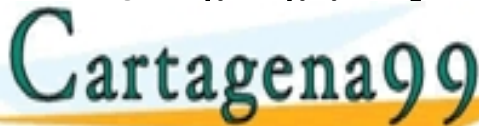
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# Source schema reverse engineering

Provide, for each input data source, the reverse engineering from the logical to the conceptual schema (ER graph)

- Tables in the logical schema normally represent either:
  - Entities
  - N:N relationships
  - Weak entities
- In the logical schema, foreign keys are always on the side of the “1” in a 1:N relationship.

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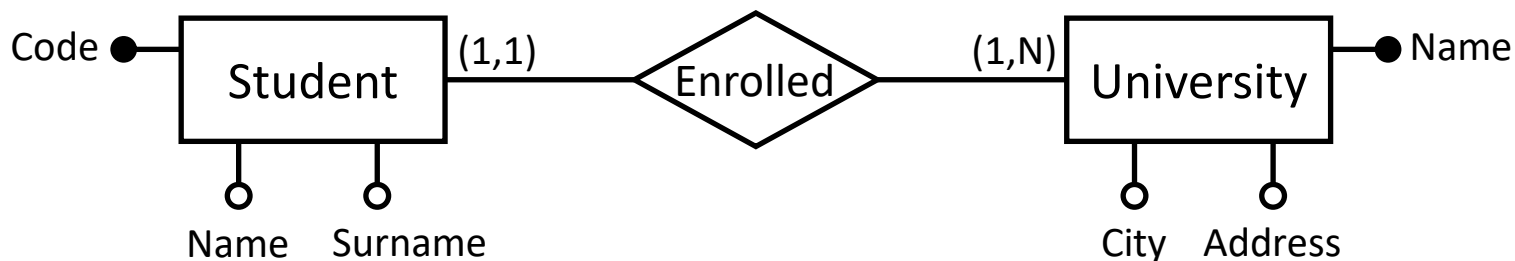
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# Weak Entities

Sometimes the attributes of an entity are not enough to identify uniquely its records:



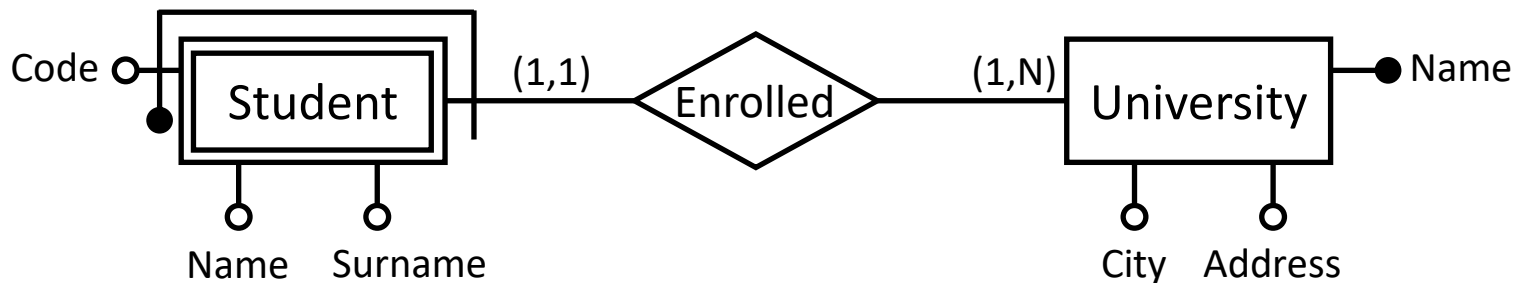
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# Weak Entities

Sometimes the attributes of an entity are not enough to identify uniquely its records:

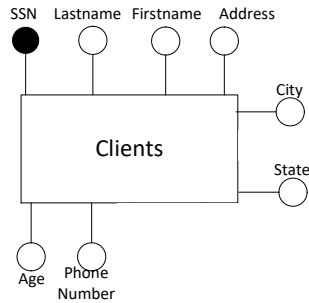


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# LALuxuryHouses

CLIENTS (SSN, Lastname, Firstname, Address, City, State, Age, PhoneNumber)



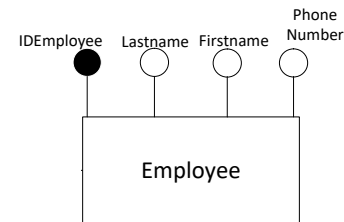
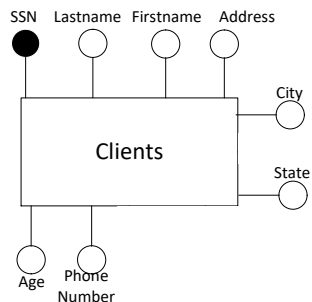
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# LALuxuryHouses

EMPLOYEE (IDEmployee, Lastname, Firstname, PhoneNumber)



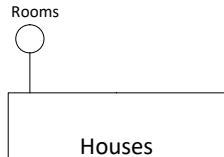
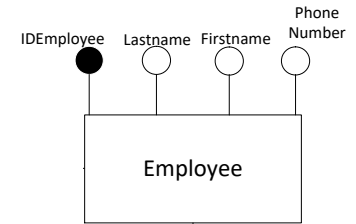
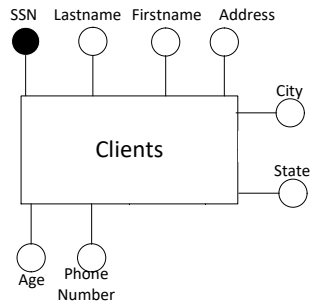
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# LALuxuryHouses

HOUSES (HouseAddress, HouseCity,  
SizeSquareMeters, Rooms)



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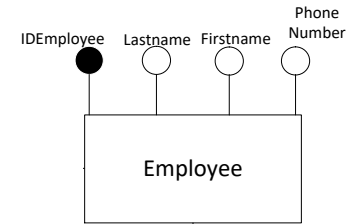
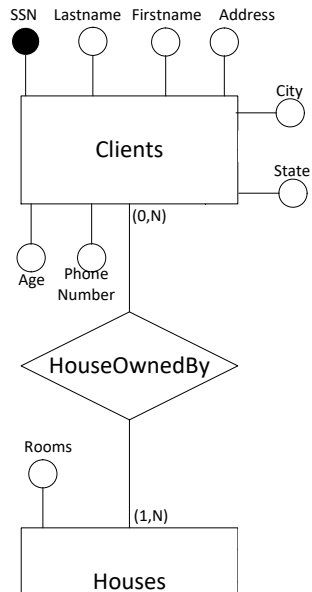
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# LALuxuryHouses

HOUSE-OWNEDBY (HouseAddress,  
HouseCity, ClientSSN)

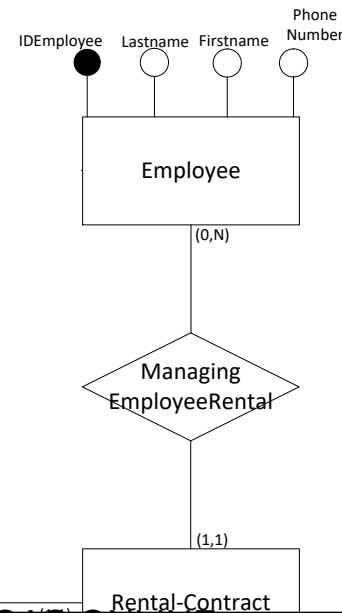
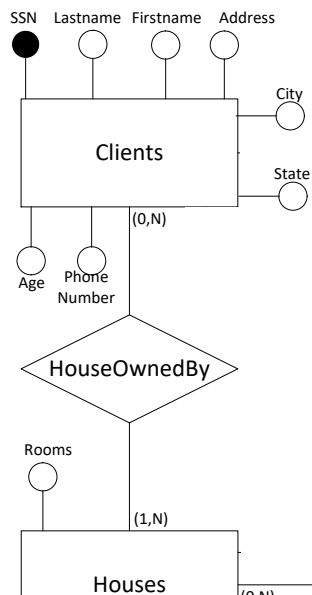


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# LALuxuryHouses

RENTAL-CONTRACT (IDRentContract,  
HouseAddress, HouseCity, StartDate,  
EndDate, AnnualCost, IDEmployee)

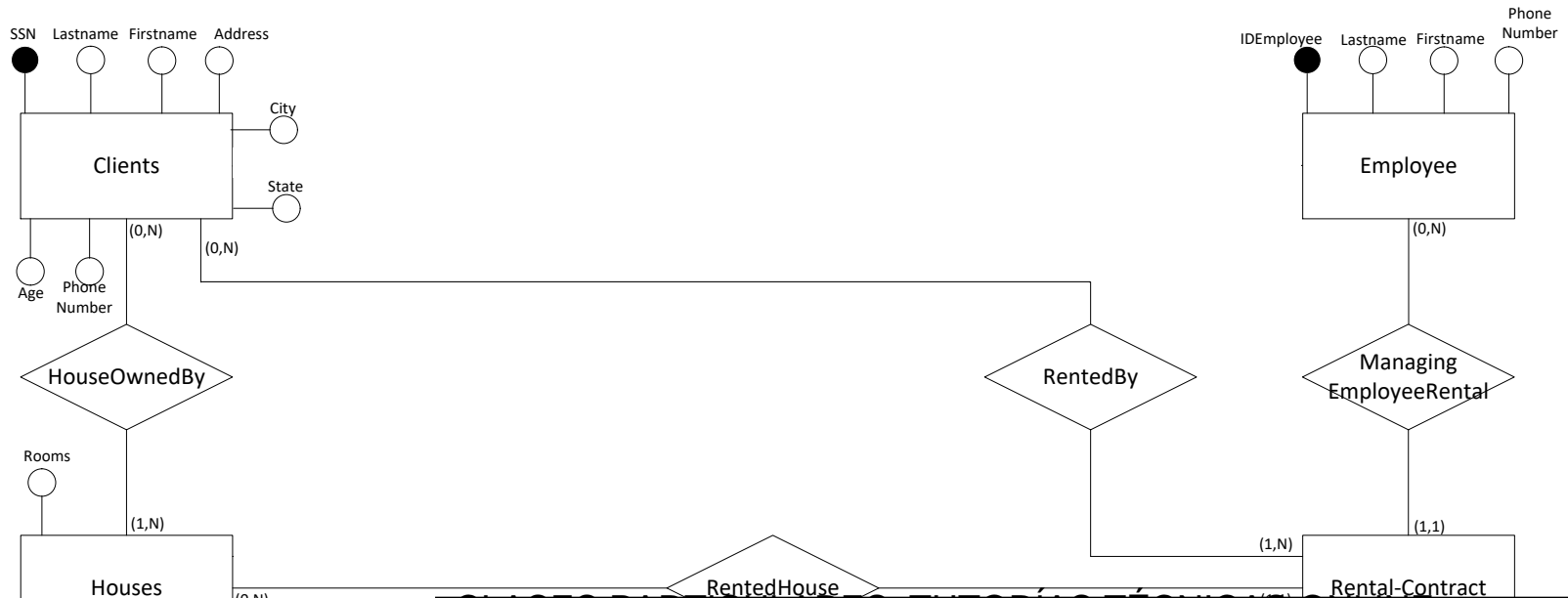


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# LALuxuryHouses

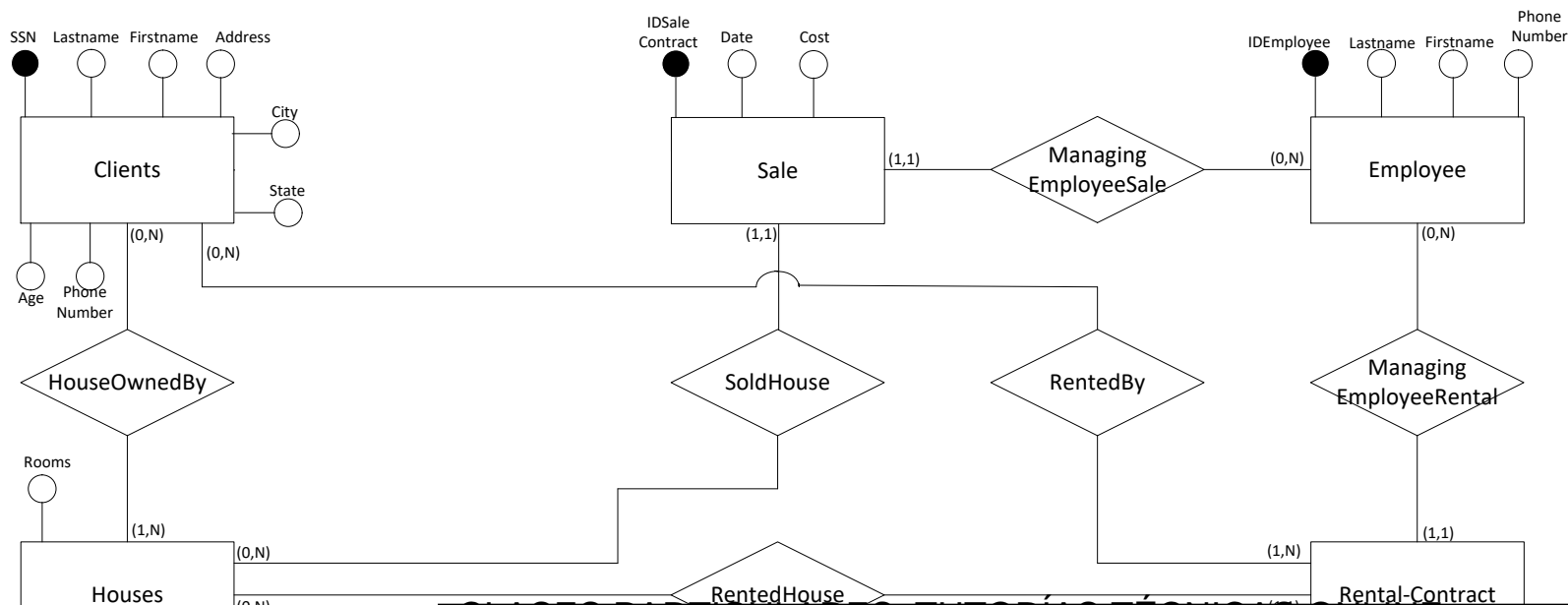
RENTEDBY (IDRentContract, ClientSSN)



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SALE (IDSaleContract, HouseAddress, HouseCity, Date, Cost, IDEmployee)

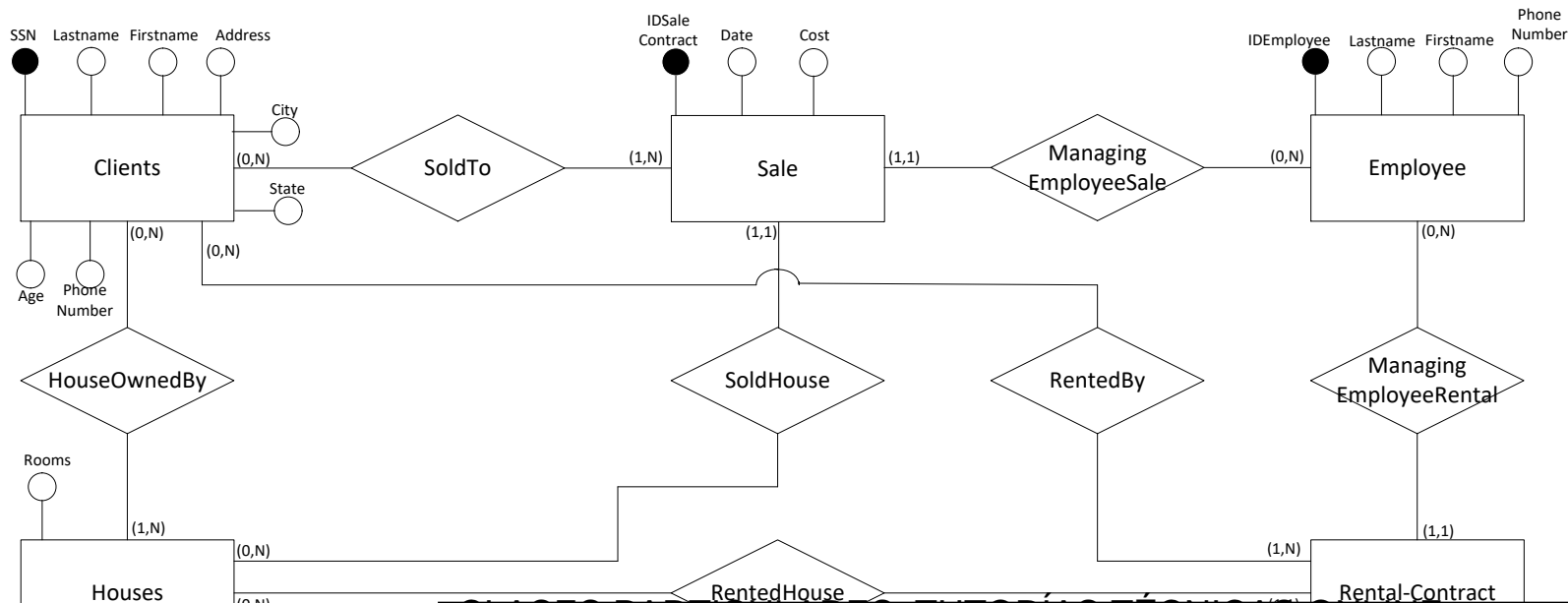


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# LALuxuryHouses

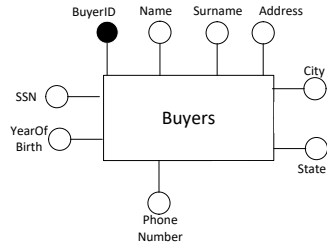
## SOLDTO (IDSaleContract, ClientSSN)



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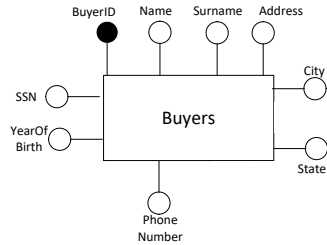


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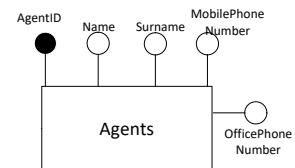
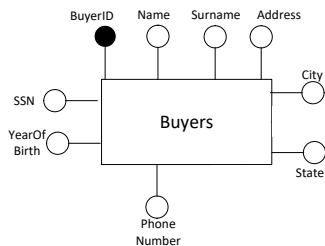


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OWNERS (OwnerID, Name, Surname)  
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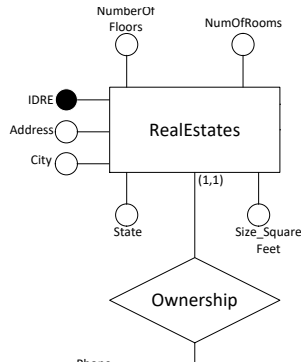
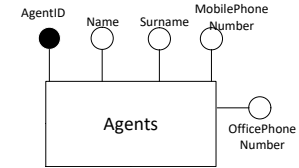
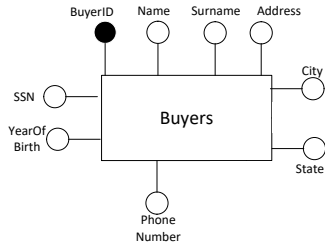
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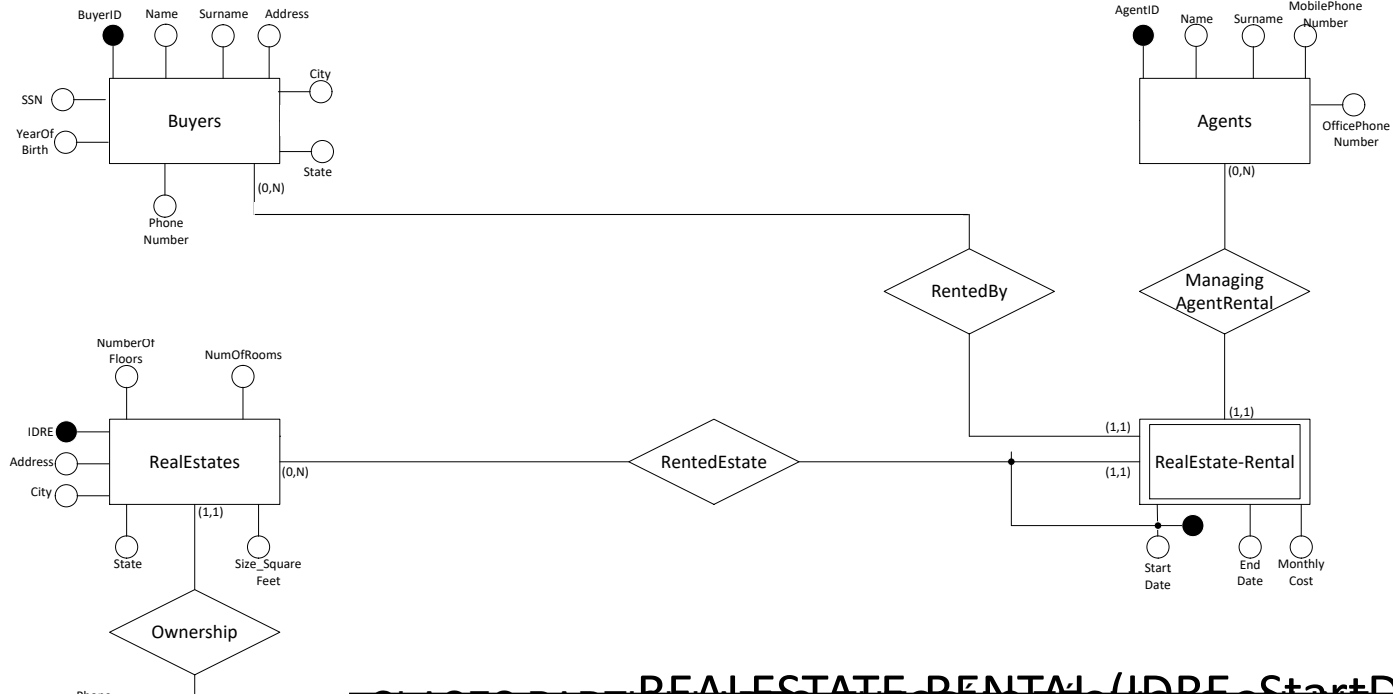


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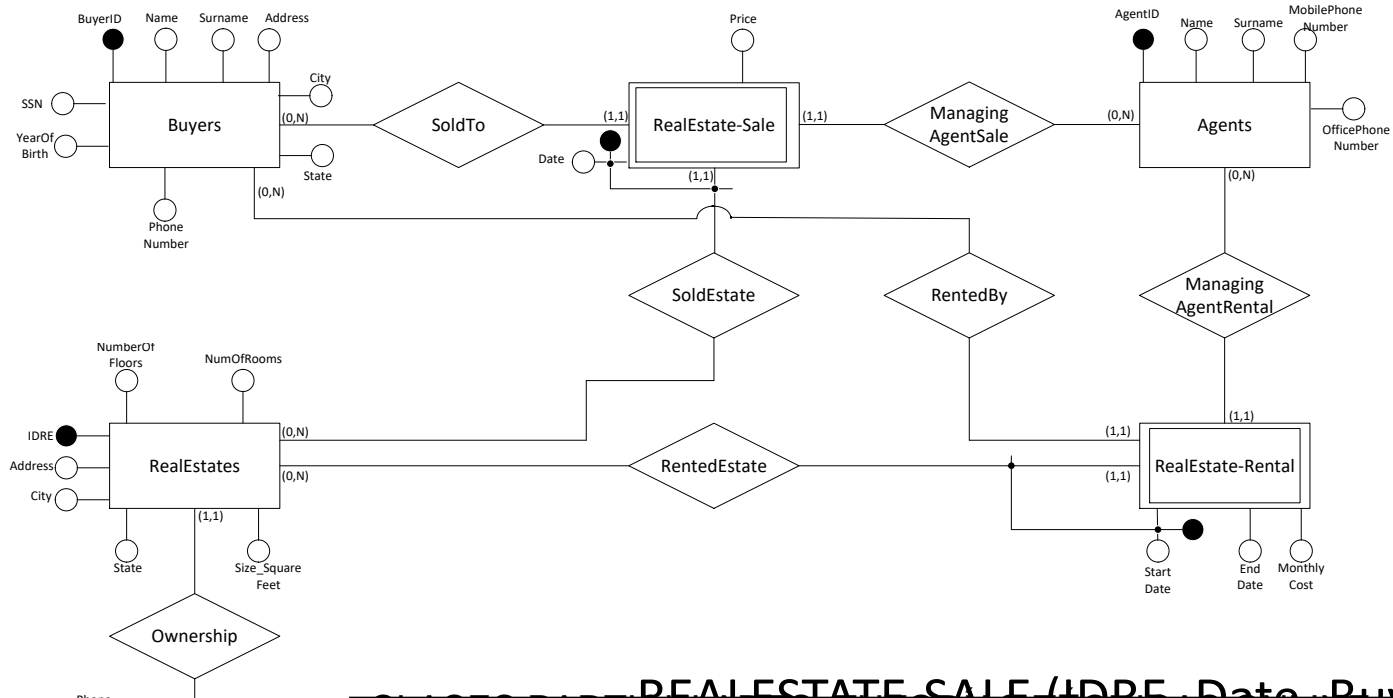
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# Related concept identification + Conflict analysis and resolution

LALuxuryHouses	USAhouses	Conflicts	Solution
Clients	Buyers / Owners		

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# Related concept identification + Conflict analysis and resolution

LALuxuryHouses	USAhouses	Conflicts	Solution
Clients	Buyers / Owners	Name conflicts	

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# Related concept identification + Conflict analysis and resolution

LALuxuryHouses	USAhouses	Conflicts	Solution
Clients	Buyers / Owners	Name conflicts	
		- Entity name	Clients



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# Related concept identification + Conflict analysis and resolution

LALuxuryHouses	USAhouses	Conflicts	Solution
Clients	Buyers / Owners	Name conflicts	
		- Entity name	Clients
		- Lastname → Surname	Lastname

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# Related concept identification + Conflict analysis and resolution

LALuxuryHouses	USAhouses	Conflicts	Solution
Clients	Buyers / Owners	Name conflicts	
		- Entity name	Clients
		- Lastname → Surname	Lastname
		- Firstname → Name	Firstname

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# Related concept identification + Conflict analysis and resolution

LALuxuryHouses	USAhouses	Conflicts	Solution
Clients	Buyers / Owners	Name conflicts	
		- Entity name	Clients
		- Lastname → Surname	Lastname
		- Firstname → Name	Firstname
		Data semantics conflicts	

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# Related concept identification + Conflict analysis and resolution

LALuxuryHouses	USAhouses	Conflicts	Solution
Clients	Buyers / Owners	Name conflicts	
		- Entity name	Clients
		- Lastname → Surname	Lastname
		- Firstname → Name	Firstname
		Data semantics conflicts	
		- Age → YearOfBirth	Compute the year of birth from the age



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# Related concept identification + Conflict analysis and resolution

LALuxuryHouses	USAhouses	Conflicts	Solution
Clients	Buyers / Owners	Name conflicts	
		- Entity name	Clients
		- Lastname → Surname	Lastname
		- Firstname → Name	Firstname
		Data semantics conflicts	
		- Age → YearOfBirth	Compute the year of birth from the age
		Key conflict	

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# Related concept identification + Conflict analysis and resolution

LALuxuryHouses	USAhouses	Conflicts	Solution
Clients	Buyers / Owners	Name conflicts	
		- Entity name	Clients
		- Lastname → Surname	Lastname
		- Firstname → Name	Firstname
		Data semantics conflicts	
		- Age → YearOfBirth	Compute the year of birth from the age
		Key conflict	
		- SSN → BuyerID/OwnerID	Use the SSN, available also in USAhouses



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# Related concept identification + Conflict analysis and resolution

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Houses	RealEstates	Name conflicts	
		- Entity name	RealEstates
		- HouseAddress → Address	Address
		- HouseCity → City	City
		- Rooms → NumOfRooms	Rooms
		Data semantics conflicts	
		- SizeSquareMeters → Size_SquareFeet	Convert in square meters
		Key conflict	
		- HouseAddress+HouseCity → IDRE	Use Address+City, available also in USAHouses
		Cardinality conflicts	
		- More owners → one owner	More owners



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# Related concept identification + Conflict analysis and resolution

LALuxuryHouses	USAHouses	Conflicts	Solution
<b>Employee</b>	Agents	Name conflicts	
		- Entity name	Employee
		- EmployeeID → AgentID	EmployeeID
		- Firstname → Name	Firstname
		- Lastname → Surname	Lastname
		- PhoneNumber → OfficePhoneNumber	OfficePhoneNumber

The logo for Cartagena99 features the text 'Cartagena99' in a stylized, teal-colored font. The '99' is significantly larger and more prominent than the 'Cartagena' part. The text is set against a light blue and orange gradient background that resembles a stylized wave or a banner.

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# Related concept identification + Conflict analysis and resolution

LALuxuryHouses	USAHouses	Conflicts	Solution
Sale	RealEstate-Sale	Name conflicts	
		- Entity name	Sale
		- Cost → Price	Cost
		Key conflict	
		- IDSaleContract → Date+IDRE	Use IDSaleContract. For USAHouses we obtain the ID concatenating IDRE and Date
		Cardinality conflicts	
		- More buyers → One buyer	More buyers



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# Related concept identification + Conflict analysis and resolution

LALuxuryHouses	USAHouses	Conflicts	Solution
Rental-Contract	RealEstate-Rental	Name conflicts	
		- Entity name	Rental-Contract
		Data semantics conflicts	
		- AnnualCost → MonthlyCost	AnnualCost (=MontlyCost*12)
		Key conflict	
		- IDRentContract →	Use IDRentContract. In USAHouses we obtain the ID concatenating IDRE and StartDate
		IDRE+StartDate	StartDate
		Cardinality conflicts	
		- More renters → One renter	More renters



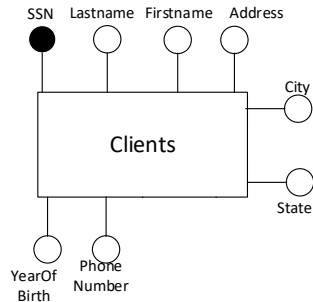
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# Global conceptual schema design

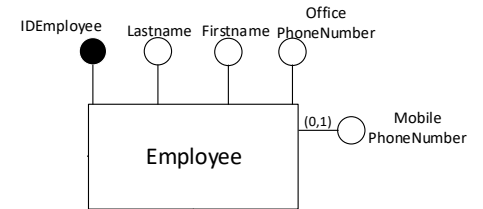
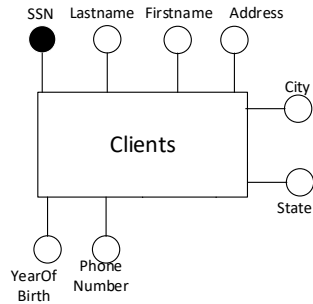


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# Global conceptual schema design

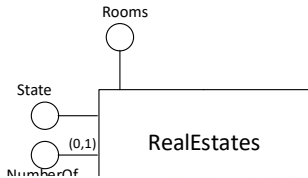
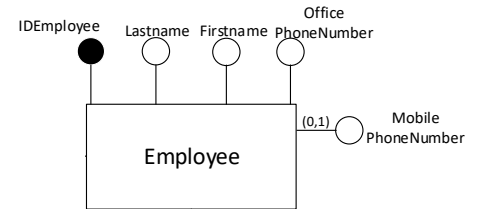
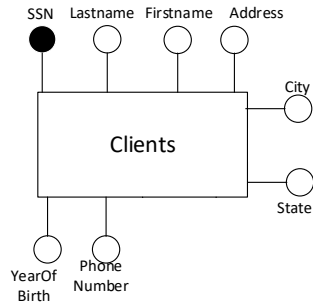


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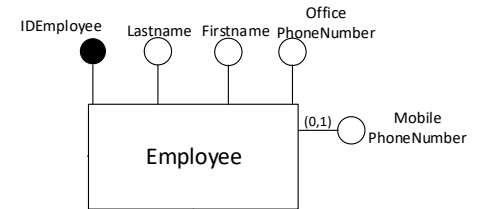
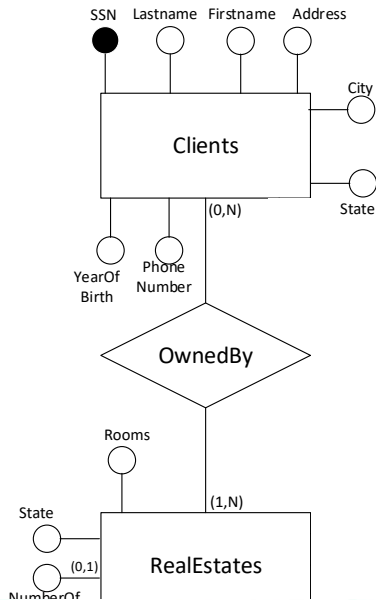
# Global conceptual schema design



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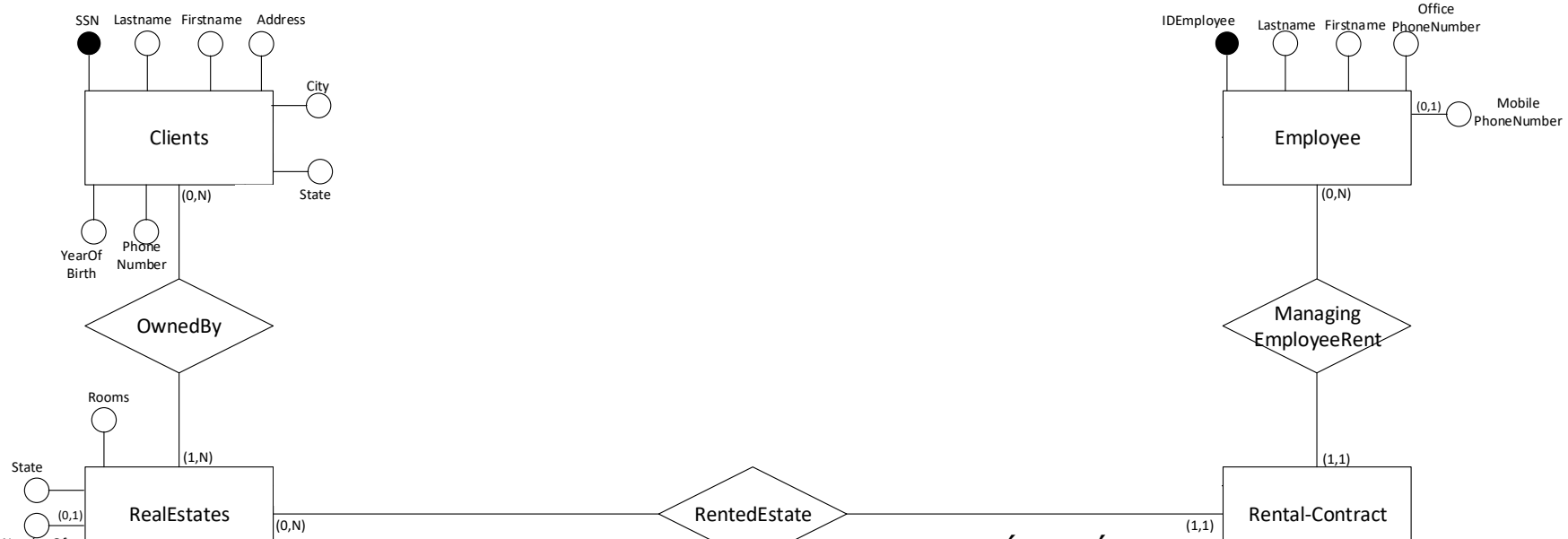


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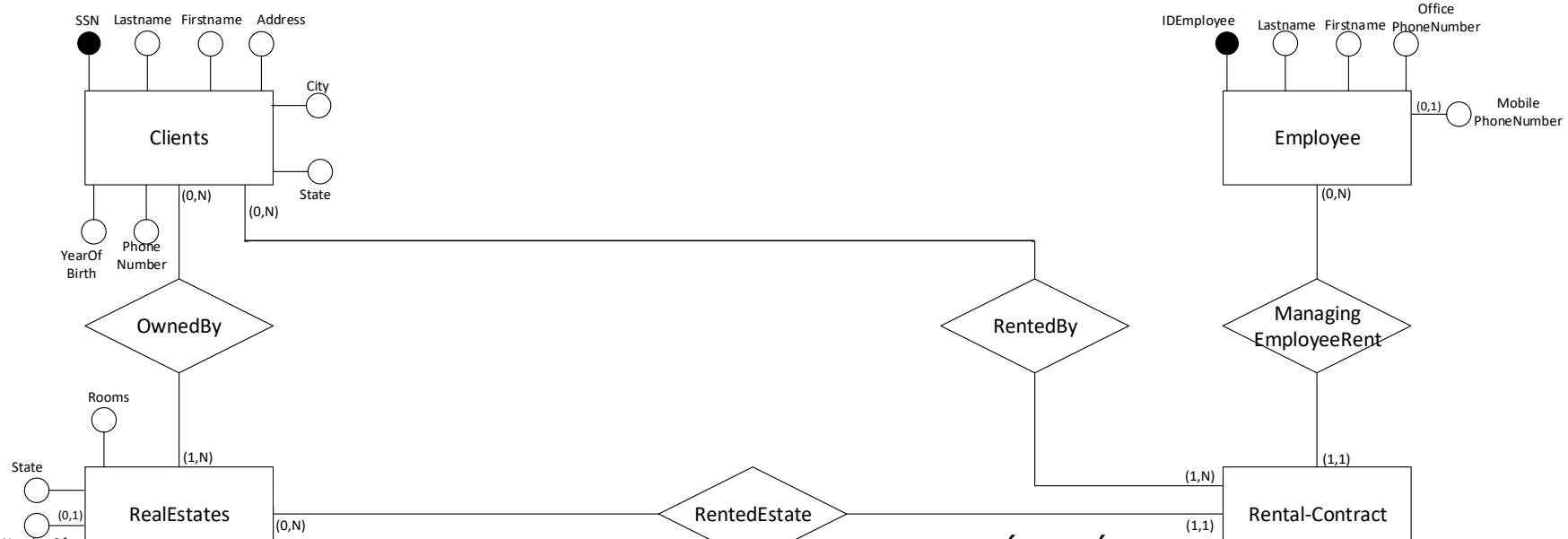
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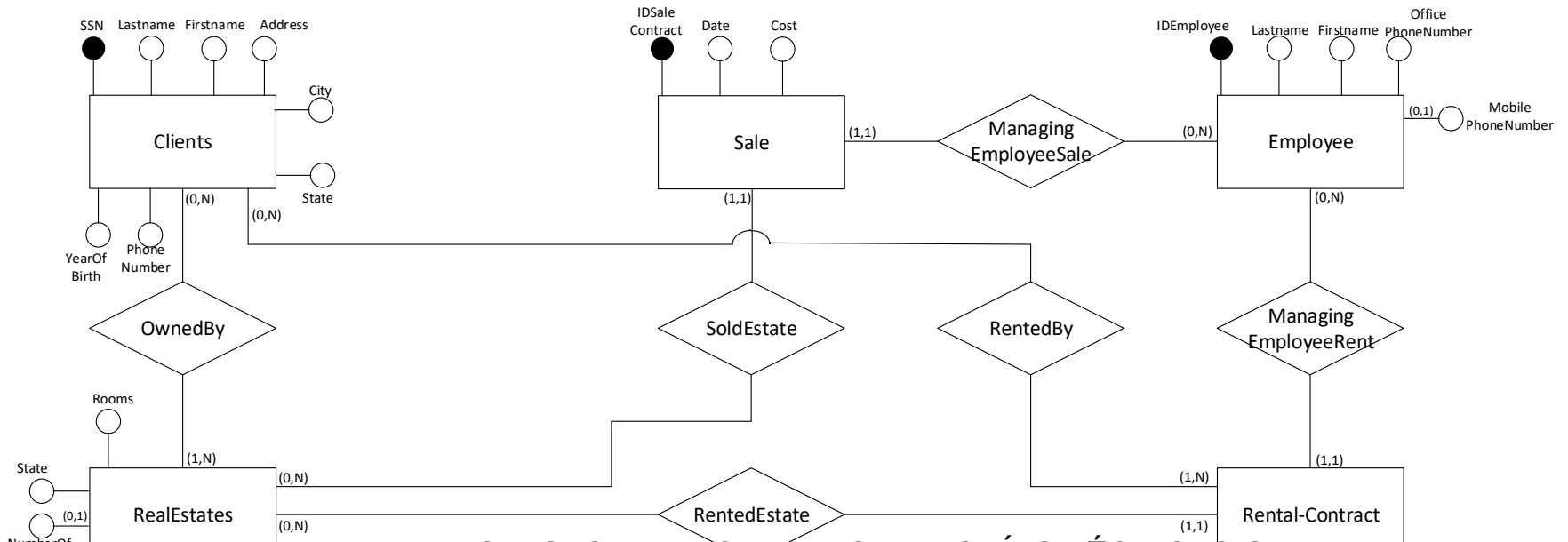
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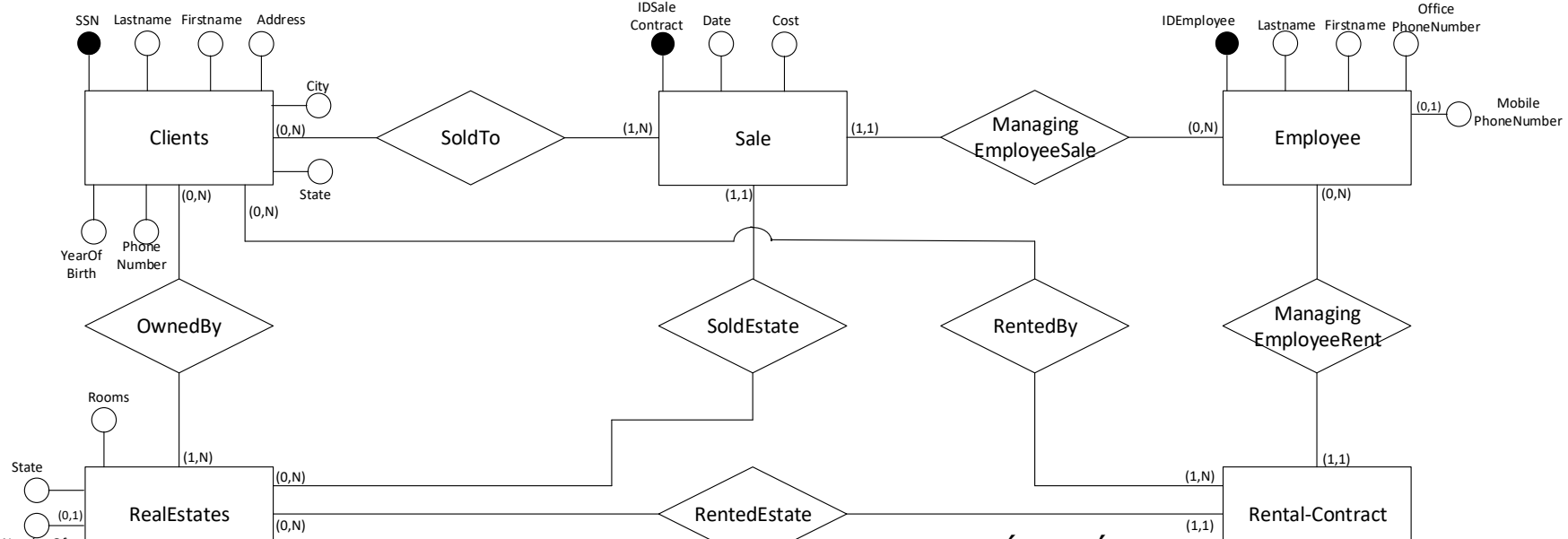
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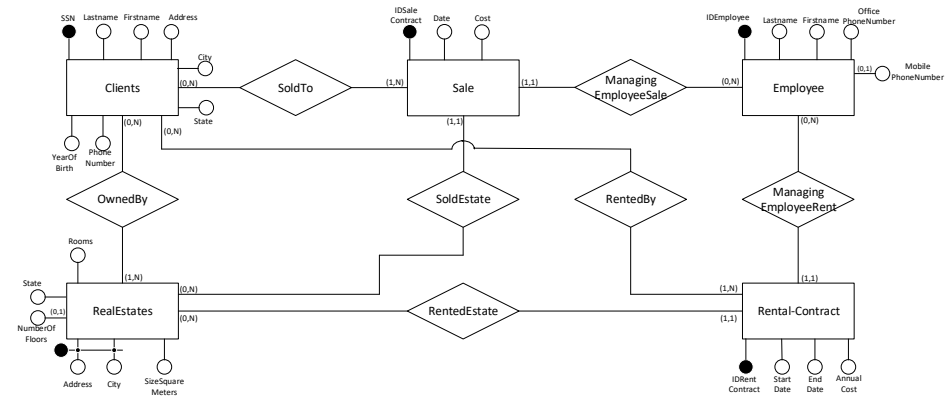
# Global conceptual schema design



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# Conceptual to logical translation of the global schema



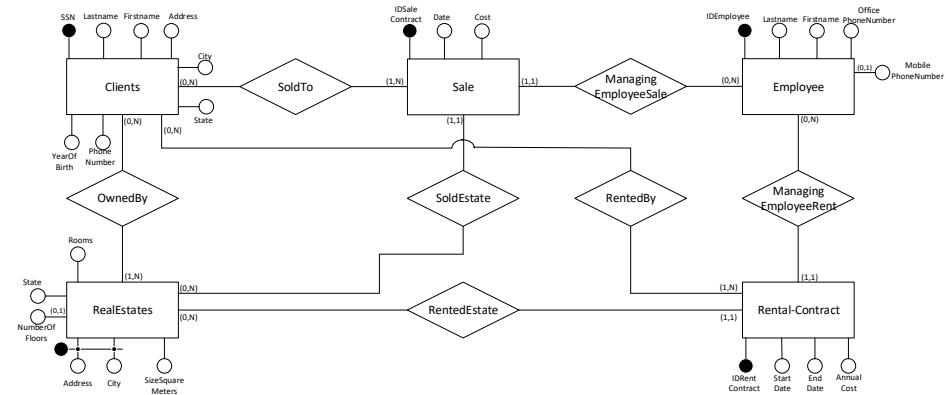
Clients (SSN, Lastname, Firstname, Address, City, State, YearOfBirth, PhoneNumber)

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# Conceptual to logical translation of the global schema



Clients (SSN, Lastname, Firstname, Address, City, State, YearOfBirth, PhoneNumber)

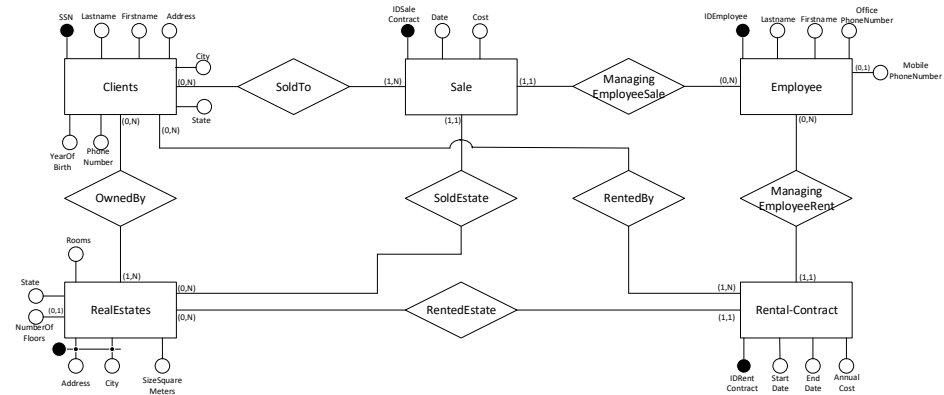
Sale (IDSaleContract, Date, Cost, EstateAddress, EstateCity, IDEmployee)

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# Conceptual to logical translation of the global schema



Clients (SSN, Lastname, Firstname, Address, City, State, YearOfBirth, PhoneNumber)

Sale (IDSaleContract, Date, Cost, EstateAddress, EstateCity, IDEmployee)

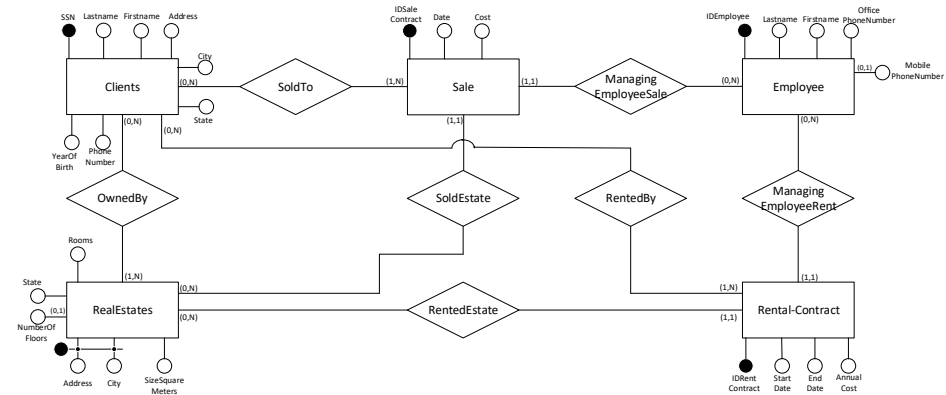
SoldTo (IDSaleContract, Client)

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# Conceptual to logical translation of the global schema



Clients (SSN, Lastname, Firstname, Address, City, State, YearOfBirth, PhoneNumber)

Sale (IDSaleContract, Date, Cost, EstateAddress, EstateCity, IDEmployee)

SoldTo (IDSaleContract, Client)

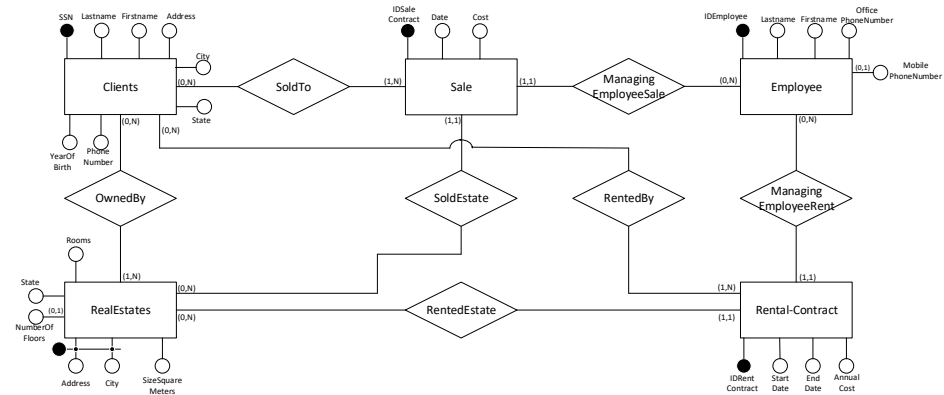
RealEstates (Address, City, State, SizeSquareMeters, Rooms, NumberOfFloors\*)

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# Conceptual to logical translation of the global schema



Clients (SSN, Lastname, Firstname, Address, City, State, YearOfBirth, PhoneNumber)

Sale (IDSaleContract, Date, Cost, EstateAddress, EstateCity, IDEmployee)

SoldTo (IDSaleContract, Client)

RealEstates (Address, City, State, SizeSquareMeters, Rooms, NumberOfFloors\*)

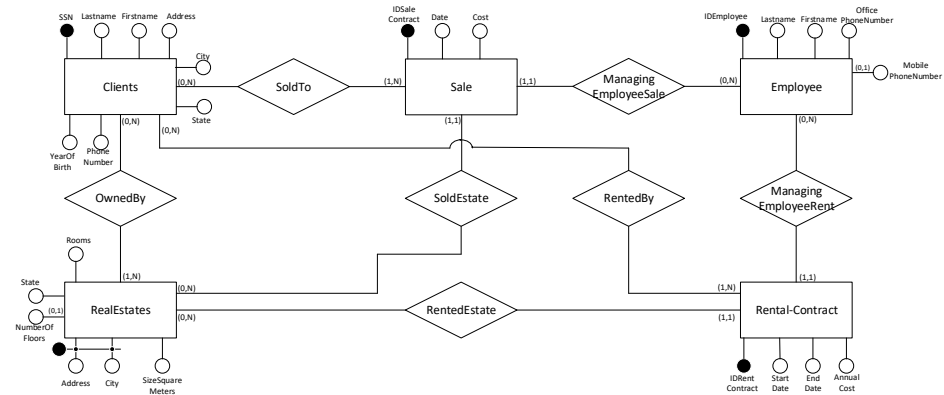
Rental-Contract (IDRentalContract, StartDate, EndDate, AnnualCost, IDEmployee, EstateAddress, EstateCity)



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# Conceptual to logical translation of the global schema



Clients (SSN, Lastname, Firstname, Address, City, State, YearOfBirth, PhoneNumber)

Sale (IDSaleContract, Date, Cost, EstateAddress, EstateCity, IDEmployee)

SoldTo (IDSaleContract, Client)

RealEstates (Address, City, State, SizeSquareMeters, Rooms, NumberOfFloors\*)

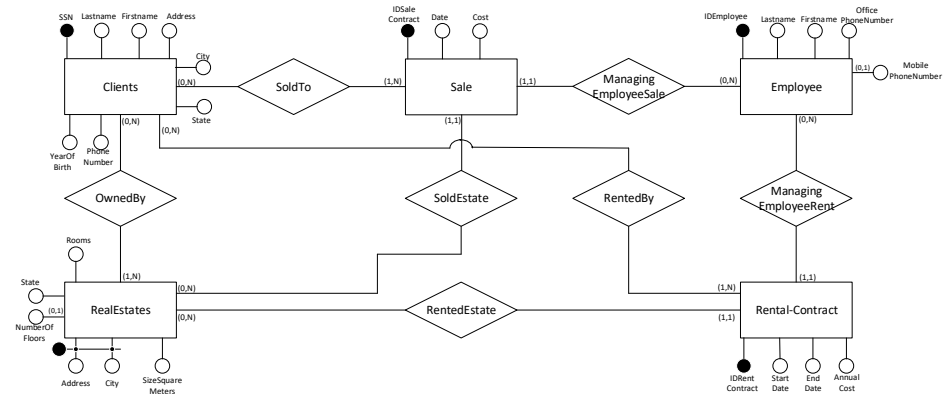
Rental-Contract (IDRentalContract, StartDate, EndDate, AnnualCost, IDEmployee, EstateAddress, EstateCity)



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# Conceptual to logical translation of the global schema



Clients (SSN, Lastname, Firstname, Address, City, State, YearOfBirth, PhoneNumber)

Sale (IDSaleContract, Date, Cost, EstateAddress, EstateCity, IDEmployee)

SoldTo (IDSaleContract, Client)

RealEstates (Address, City, State, SizeSquareMeters, Rooms, NumberOfFloors\*)

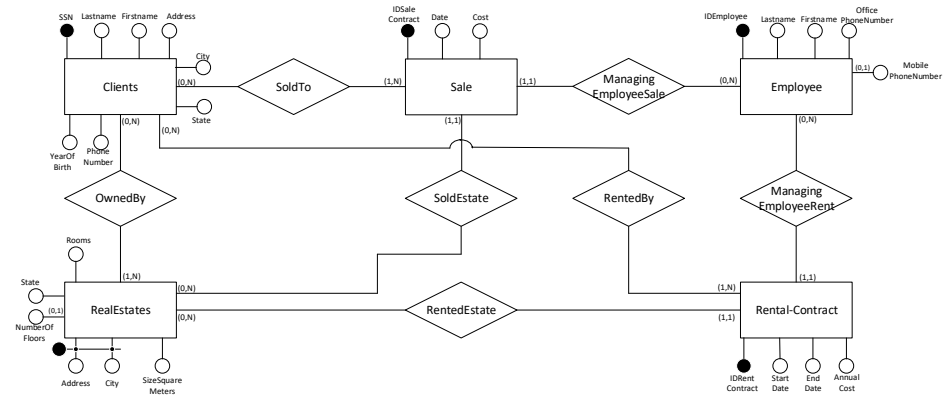
Rental-Contract (IDRentalContract, StartDate, EndDate, AnnualCost, IDEmployee, EstateAddress, EstateCity)

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# Conceptual to logical translation of the global schema



Clients (SSN, Lastname, Firstname, Address, City, State, YearOfBirth, PhoneNumber)

Sale (IDSaleContract, Date, Cost, EstateAddress, EstateCity, IDEmployee)

SoldTo (IDSaleContract, Client)

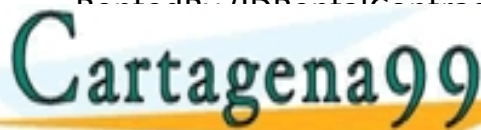
RealEstates (Address, City, State, SizeSquareMeters, Rooms, NumberOfFloors\*)

Rental-Contract (IDRentalContract, StartDate, EndDate, AnnualCost, IDEmployee, EstateAddress, EstateCity)

RentedBy (IDRentContract, Client)

Employee (IDEmployee, Lastname, Firstname, Office, Mobile, MobilePhoneNumber)

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# GAV mapping

```
CREATE VIEW GlobalSchema.TableX(attributes of GlobalSchema.TableX  
in the order as in GlobalSchema.TableX) AS (
```

SOURCE 1

```
SELECT      attributes from SourceSchema1 but in the order as  
            in GlobalSchema.TableX  
FROM        SourceSchema1.TableY1, SourceSchema1.TableY2, ...  
WHERE      ...
```

UNION

SOURCE 2

```
SELECT      attributes from SourceSchema2 but in the order as  
            in GlobalSchema.TableX  
FROM        SourceSchema2.TableZ1, SourceSchema2.TableZ2
```

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# GAV mapping - Clients

**CREATE VIEW** USARealEstateCompany.Clients (SSN, Lastname, Firstname, Address, City, State, YearOfBirth, PhoneNumber) **AS** (

**SELECT** SSN, Lastname, Firstname, Address, City, State, CurrentYear()-Age, PhoneNumber  
**FROM** LALuxuryHouses.Clients

**UNION**

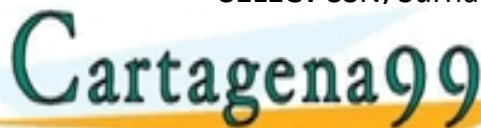
**SELECT** SSN, Surname, Name, Address, City, State, YearOfBirth, PhoneNumber  
**FROM** USAHouses.Buyers

**UNION**

**SELECT** SSN, Surname, Name, Address, City, State, YearOfBirth, PhoneNumber

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The logo for Cartagena99 features the text 'Cartagena99' in a stylized, teal-colored font. The '99' is significantly larger and more prominent than the 'Cartagena' part. Below the text, there is a horizontal brushstroke that transitions from light blue on the left to orange on the right.

# GAV mapping - RealEstates

**CREATE VIEW** USARealEstateCompany.RealEstates (Address, City, State, SizeSquareMeters, Rooms, NumberOfFloors) **AS** (

**SELECT** HouseAddress, HouseCity, 'California', SizeSquareMeters, Rooms, **null**

**FROM** LALuxuryHouses.Houses

**UNION**

**SELECT** Address, City, State, SizeSquareFeet\*0.0929, NumOfRooms, NumberOfFloors

**FROM** USAHouses.RealEstates

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# Keygen

Since we do data integration with the union operator we are assuming everything to be disjoint, but...

... it does not mean primary keys are unique!

## Source1

ID=1 Name="A"

ID=2 Name="B"

ID=3 Name="C"

ID=4 Name="D"

ID=5 Name="E"

## Source2

ID=1 Name="F"

ID=2 Name="G"

ID=3 Name="H"

ID=4 Name="I"

The logo for Cartagena99 features the text "Cartagena99" in a stylized, teal-colored font. The "99" is significantly larger and more prominent than the "Cartagena" part. The text is set against a light blue and white background with a subtle wave-like pattern.

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# GAV mapping - Sale

**CREATE VIEW** USARealEstateCompany.Sale (IDSaleContract, Date, Cost, EstateAddress, EstateCity,

IDEmployee) **AS** ( 123410122019-LALuxuryHouses

**SELECT** KeyGenSale (IDSaleContract, 'LALuxuryHouses'), Date, Cost, HouseAddress, HouseCity, KeyGenEmployee(IDEmployee, 'LALuxuryHouses')

**FROM** LALuxuryHouses.Sale

**UNION**

1234 10122019

**SELECT** KeyGenSale(R.IDRE | |S.Date, 'USAHouses'), S.Date, S.Price, R.Address, R.City, KeyGenEmployee(S.AgentID, 'USAHouses')

**FROM** USAHouses.RealEstate-Sale **AS** S, USAHouses.RealEstates **AS** R

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# GAV mapping - SoldTo

```
CREATE VIEW USARealEstateCompany.SoldTo (IDSaleContract, Client) AS (  
  SELECT KeyGenSale(IDSaleContract, 'LALuxuryHouses'), ClientSSN  
  FROM LALuxuryHouses.SoldTo
```

**UNION**

```
  SELECT KeyGenSale(R.IDRE || R.Date, 'USAHouses'), B.SSN  
  FROM USAHouses.RealEstate-Sale AS R, USAHouses.Buyers AS B
```

The logo for Cartagena99 features the text 'Cartagena99' in a stylized, teal-colored font. The '99' is significantly larger and more prominent than the 'Cartagena' part. The text is set against a light blue and orange gradient background that resembles a stylized wave or a banner.

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# GAV mapping - OwnedBy

**CREATE VIEW** USARealEstateCompany.OwnedBy (EstateAddress, EstateCity, Client) **AS** (

**SELECT** HouseAddress, HouseCity, ClientSSN

**FROM** LALuxuryHouses.House-OwnedBy

**UNION**

**SELECT** R.Address, R.City, O.SSN

**FROM** RealEstates **AS** R, Owners **AS** O

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# GAV mapping - Employee

```
CREATE VIEW USARealEstateCompany.Employee (IDEmployee, Lastname,  
Firstname, OfficePhoneNumber, MobilePhoneNumber) AS (  
    SELECT KeyGenEmployee(IDEmployee, 'LALuxuryHouses'), Lastname,  
        Firstname, PhoneNumber, null  
FROM LALuxuryHouses.Employee
```

**UNION**

```
SELECT KeyGenEmployee(AgentID, 'USAHouses'), Surname, Name,  
    OfficePhoneNumber, MobilePhoneNumber  
FROM USAHouses.Agents
```

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# Query formulation on the global schema

**Consider query Q posed on USRealEstateCompany's schema and write it either in Datalog or SQL.**

**Q:** *“Find the name and surname of the buyers who live in the city of Los Angeles and have bought at least one house larger than 100 square meters located in the city of Beverly Hills”.*

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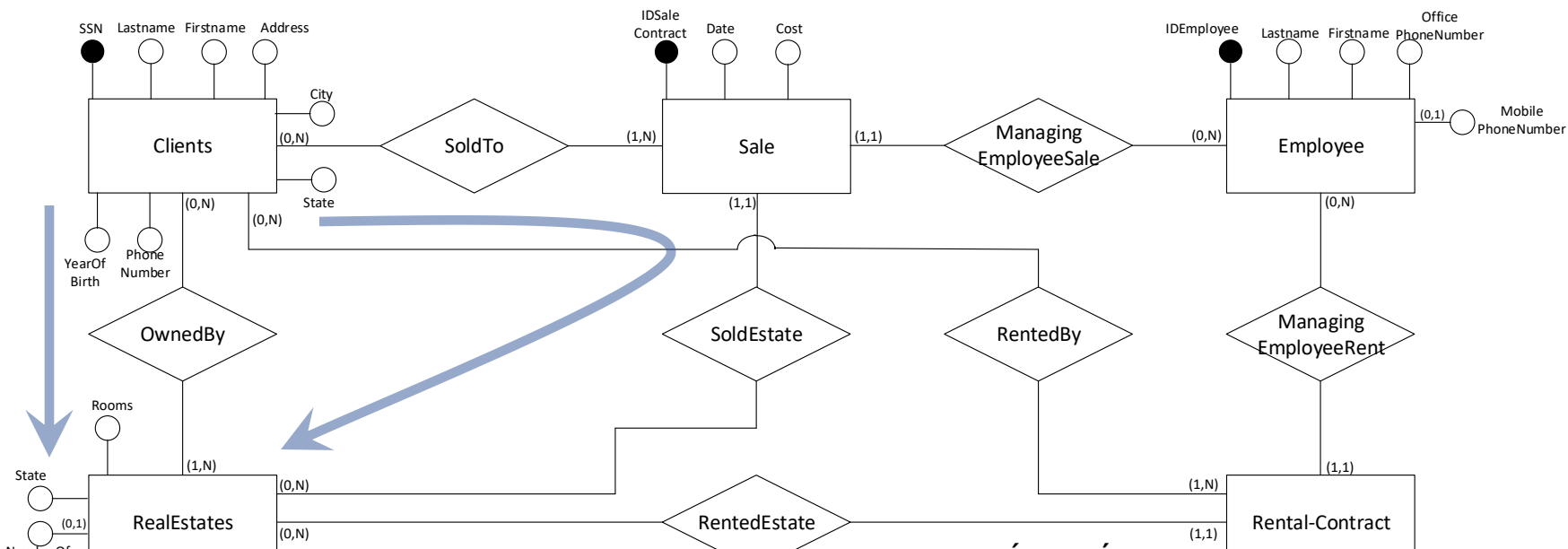
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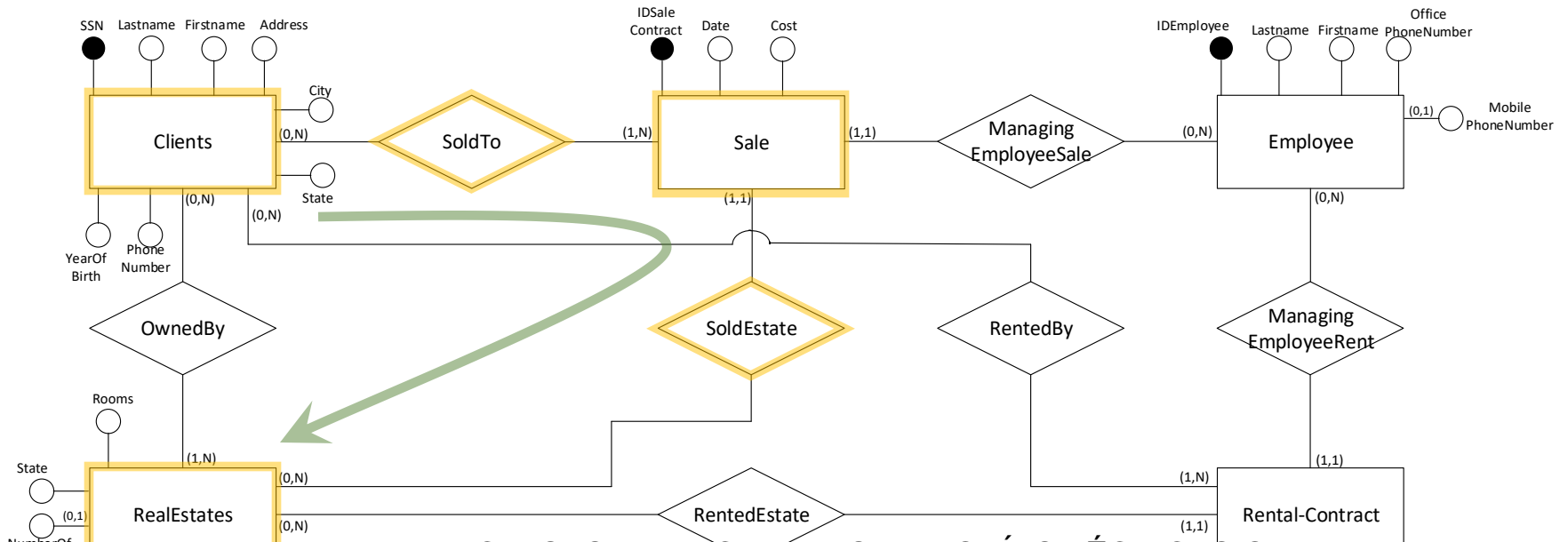
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# Query formulation on the global schema

Consider query Q posed on USARealEstateCompany's schema and write it either in Datalog or SQL.

**Q:** *“Find the name and surname of the buyers who live in the city of Los Angeles and have bought at least one house larger than 100 square meters located in the city of Beverly Hills”.*

**SELECT DISTINCT** C.Lastname, C.Firstname  
**FROM** USARealEstateCompany.Clients **AS** C, USARealEstateCompany.Sale **AS** S,  
USARealEstateCompany.SoldTo **AS** ST, USARealEstateCompany.RealEstates  
**AS** R

**WHERE** C.CSN = ST.Client AND ST.IDSaleContract = S.IDSaleContract AND

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# Query rewriting

```
SELECT C.Lastname, C.Firstname
FROM LALuxuryHouses.Clients AS C, LALuxuryHouses.SoldTo AS ST,
      LALuxuryHouses.Sale AS S, LALuxuryHouses.Houses AS H
WHERE C.SSN=ST.ClientSSN AND ST.IDSaleContract=S.IDSaleContract AND
      H.HouseAddress=S.HouseAddress AND H.HouseCity=S.HouseCity AND
      C.City='Los Angeles' AND H.SizeSquareMeters>100 AND H.City='Beverly
      Hills'
```

**UNION**

```
SELECT B.Surname AS Lastname, B.Name AS Firstname
```

```
FROM USAHouses.Buyers AS B, USAHouses.RealEstateSale AS S
```

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```
WHERE H.SizeSquareMeters > 100 AND H.City = 'Beverly Hills'
```

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