

## Knowledge-Based Systems

# Ontology Modelling: From Semantic Networks to Ontologies

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# RDF: Standard of Semantic Network

- Building block of RDF: subject-property-value



The screenshot shows a Google search for "Obama". The search bar at the top contains the word "Obama". Below the search bar, there are tabs for "Web", "Images", "News", "Videos", "Books", "More", and "Search tools". The search results show "About 156,000,000 results (0.33 seconds)".

The first result is "Barack Obama" with the URL "www.barackobama.com/". Below it is a snippet: "Sign the petition to say it's time to give America a raise. Sign the petition. 'You and I, as citizens, have the power to set this country's course.' —President Obama."

The second result is "Barack Obama - Wikipedia, the free encyclopedia" with the URL "en.wikipedia.org/wiki/Barack\_Obama". Below it is a snippet: "Barack Hussein Obama II is the 44th and current President of the United States, and the first African American to hold the office. Born in Honolulu, Hawaii, ... Michelle Obama - Ann Dunham - Barack Obama, Sr. - Occidental College".

The third result is "News for Obama". It includes a news item from BBC News: "European Reassurance Initiative: Obama announces \$1bn ...". The snippet says: "President Barack Obama announces plans for a \$1bn fund to increase US military deployments to Europe, during a visit to Poland."

Below the news item is a link to "Obama assures eastern Europe that the US will not abandon it" from The Guardian, dated 5 hours ago. Another link is "Obama urges Russia's Putin to make choice over Ukraine ..." from CNN, dated 6 hours ago.

There is a link to "More news for Obama".

The fourth result is "President Barack Obama | The White House" with the URL "www.whitehouse.gov". Below it is a snippet: "Barack H. Obama is the 44th President of the United States. His story is the American story — values from the heartland, a middle-class upbringing in a strong ...".

The fifth result is "Barack Obama (BarackObama) on Twitter" with the URL "https://twitter.com/BarackObama". Below it is a snippet: "The latest from Barack Obama (@BarackObama). This account is run by Organizing for Action staff. Tweets from the President are signed -bo. Washington, DC."

On the right side of the search results, there is a knowledge panel for "Barack Obama". It shows a large image of Barack Obama and a smaller image of him with his family. Below the images, it says "Barack Obama" and "4,269,608 followers on Google+". It then provides biographical information: "Barack Hussein Obama II is the 44th and current President of the United States, and the first African American to hold the office. Wikipedia", "Born: August 4, 1961 (age 52), Honolulu, Hawaii, United States", "Spouse: Michelle Obama (m. 1992)", "Parents: Ann Dunham, Barack Obama Sr.", "Children: Natasha Obama, Malia Ann Obama", "Siblings: Malik Abongo Obama, Maya Soetoro-Ng, Auma Obama, more", and "Education: Harvard Law School (1988–1991), more".

Below the biographical information, there is a section for "Recent posts" with a snippet: "The new carbon pollution standards are a big deal in the fight against climate change: http://ofa.bo/IE 2 hours ago".

At the bottom of the knowledge panel, there is a section for "People also search for" with a link to "View 15+ more". It shows five small images of people: Michelle Obama, Vladimir Putin, George W. Bush, Mitt Romney, and Hillary Clinton.

# Some Example RDF Triples in N3

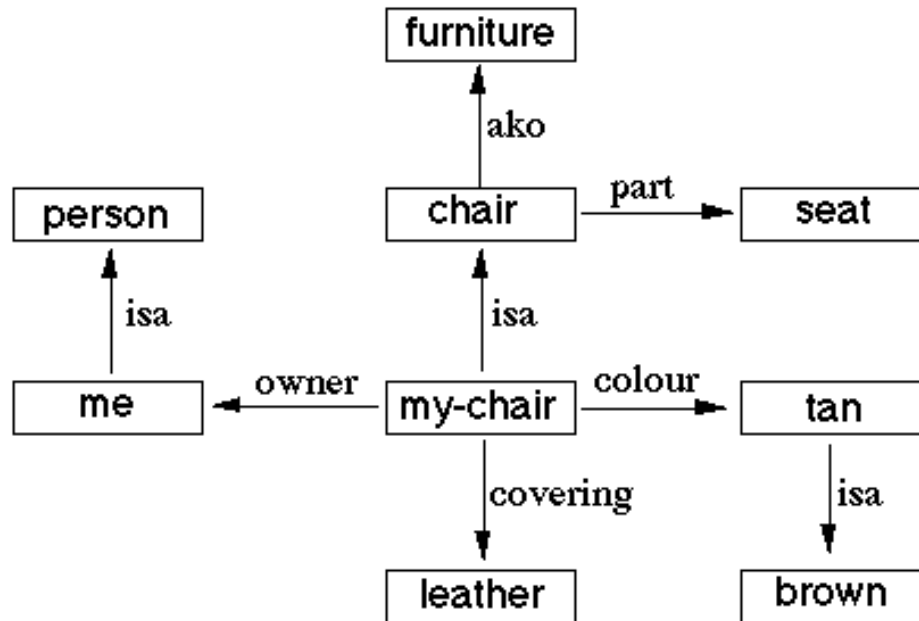
- [ggl:barak-obama **rdf:type** ggl:Politician .]
- [ggl:Politician **rdfs:subClassOf** ggl:Person .]
- [ggl:barak-obama ggl:born 1961-08-04 .]
- [ggl:barak-obama ggl:spouse ggl:michelle-obama .]
- [ggl:barak-obama ggl:education ggl:harvard-law-school .]





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# RDF and Semantic Network



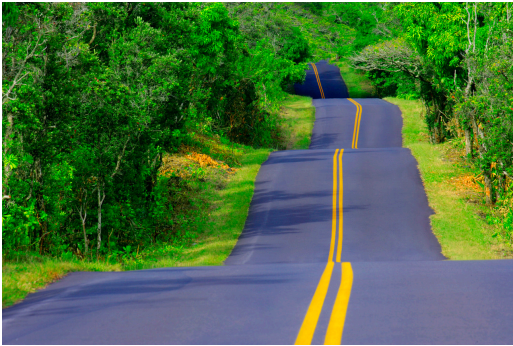
[my-chair colour tan .]

[my-chair **rdf:type** chair .]

[chair **rdfs:subClassOf** furniture .]

...

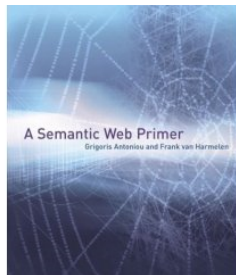
# Roadmap



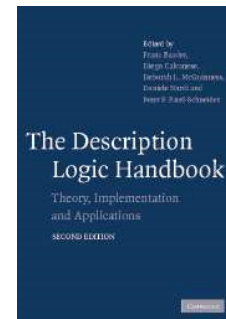
- Foundation
  - KR, ontology and rule; set theory
- Knowledge capture
- Knowledge representation
  - Ontology: Semantic Web standards RDF and OWL, Description Logics
  - Rule: Jess
- Knowledge reasoning
  - Ontology: formal semantics, tableaux algorithm
  - Rule: forward chaining, backward chaining
- Knowledge reuse and evaluation
- Meeting the real world
  - Jess and Java, Uncertainty

# Lecture Outline

- Motivation
- RDF, Semantic Networks and OWL
- From Semantic Networks to OWL Ontologies
- Practical



[Section 4.1 - 4.3]



[Chapter 14]

# Motivations



- Need to better understand RDF (standard of semantic network)
  - in terms of reasoning
  - in terms of relation to database
- Many human knowledge is still represented in natural language
- Ontology modelling
  - natural language -> semantic network
  - semantic network -> OWL ontologies

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# RDF Schema Entailment Rules (1)

- [rdfs2]
  - [p rdfs:domain C .] [a p b .]  $\Rightarrow$  [a rdf:type C .]
- [rdfs3]
  - [p rdfs:range D .] [a p b .]  $\Rightarrow$  [b rdf:type D .]
- [rdfs5]
  - [p1 rdfs:subPropertyOf p2 .] [p2 rdfs:subPropertyOf p3 .]  
 $\Rightarrow$   
[p1 rdfs:subPropertyOf p3 .]

# RDF Schema Entailment Rules (2)

- [rdfs7]
  - [p1 rdfs:subPropertyOf p2 .] [a p1 b .] => [a p2 b .]
- [rdfs9]
  - [C rdfs:subClassOf D .] [b rdf:type C .] => [b rdf:type D .]
- [rdfs11]
  - [C1 rdfs:subClassOf C2 .] [C2 rdfs:subClassOf C3 .] => [C1 rdfs:subClassOf C3 .]

# Example: RDF Schema Entailment Rules

- Example entailment rule [rdfs9]:

$[b \text{ rdf:type } C .], [C \text{ rdfs:subClassOf } D .] \Rightarrow [b \text{ rdf:type } D .]$

- Since we have

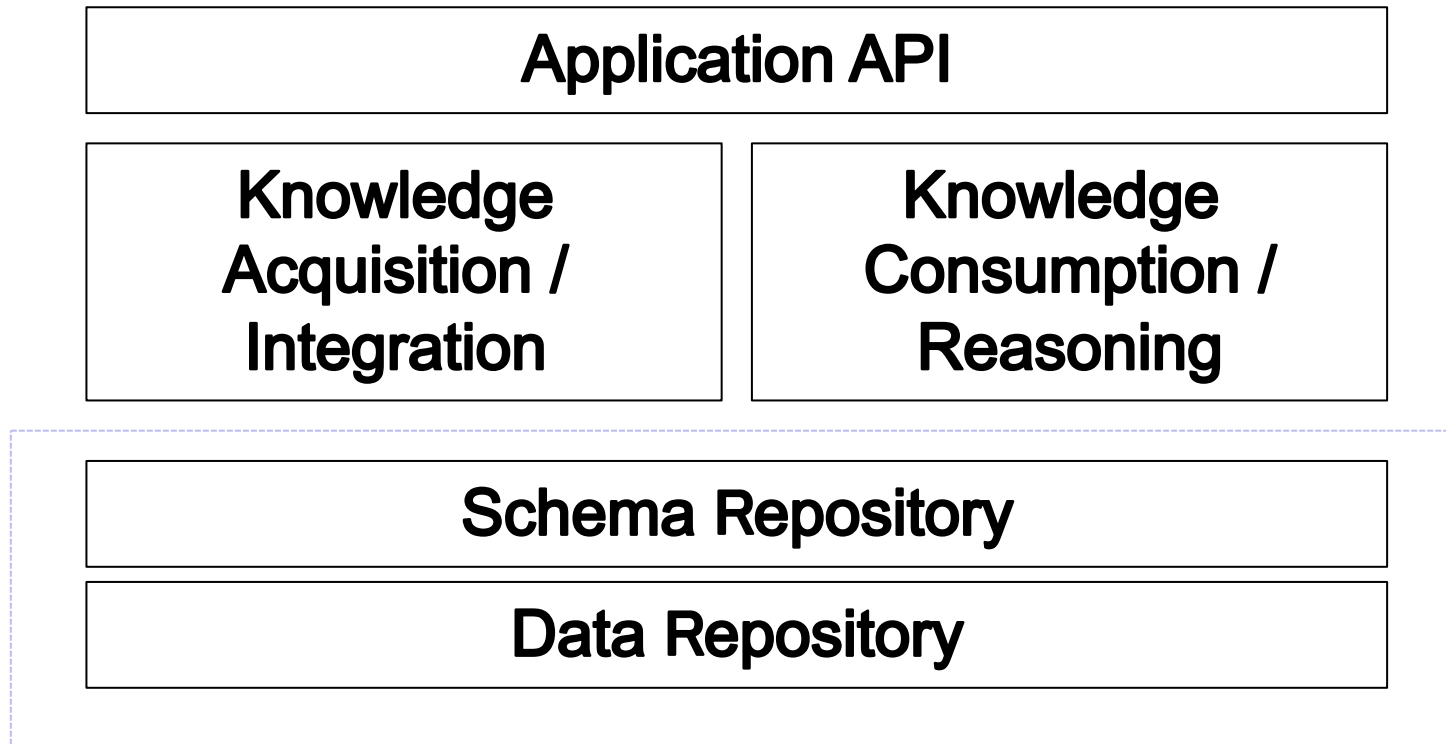
$[my\text{-}chair \text{ rdf:type } chair .]$

$[chair \text{ rdfs:subClassOf } furniture .]$

by applying the above rule, we have

$[my\text{-}chair \text{ rdf:type } furniture .]$

# Architecture of Knowledge Based Systems

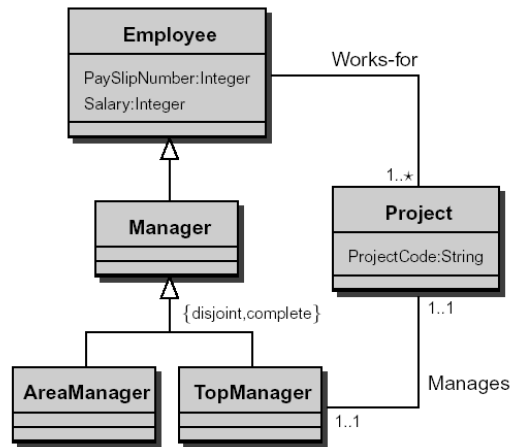


# Knowledge Representation in RDF

- Start from a semantic network
- Transformed from a relational database
- From natural language sentences
- Question: can you translate the following statement into RDF?
  - Student is a person `[Student rdfs:subClassOf Person .]`
  - Student attends a course `[attend rdfs:domain Student .]`  
`[attend rdfs:range Course .]`
  - Professor teaches a course `[teach rdfs:domain Professor .]`  
`[teach rdfs:range Course .]`
  - Person has first name, last name and email address

Not representable in RDF

# Key Modelling Elements in RDF/OWL



- Key elements: object, class (concept), property (relation)
  - in RDF, everything is a resource, including classes and properties
- A class is a set of objects
  - Employee: {E1, E2, E3, E4}
  - Project: {P1, P2}
- A property is a set to pairs (tuples) of objects
  - Works-for: {<E1,P1>, <E2,P1>, <E2,P2>, <E3,P1>, <E3,P2>, <E4,P2>}

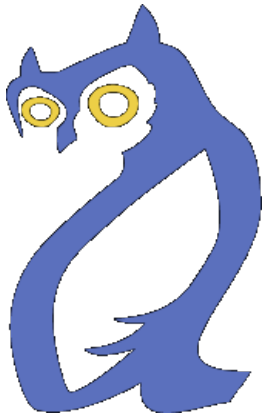
# Database and RDF

- An RDF statement is a data unit with global and linkable ids for data and schema

Student ID	Name	take-course
p001	John	cs3019
p002	Tom	cs3023

- [csd:p001 rdf:type csd:Student .]
- [csd:p002 rdf:type csd:Student .]
- [csd:p001 csd:name “John” .]
- [csd:p002 csd:name “Tom” .]
- [csd:p001 csd:take-course csd:cs3019 .]
- [csd:p002 csd:take-course csd:cs3023 .]

# Two Types of Properties in OWL



- In OWL there are two kinds of properties
  - **Object properties**, which relate objects to other objects
    - E.g. take-course, supervises
  - **Datatype properties**, which relate objects to datatype values
    - E.g. Name, title, age, etc.

Student ID	Name	take-course
p001	John	cs3019
p002	Tom	cs3023



# Database and RDF

- **Question:** How about the foreign key to the Course table?
- **Answer??:** [csd:take-course rdfs:range csd:Course .]

(very close, but not quite, due to the difference between open world and closed world assumptions)

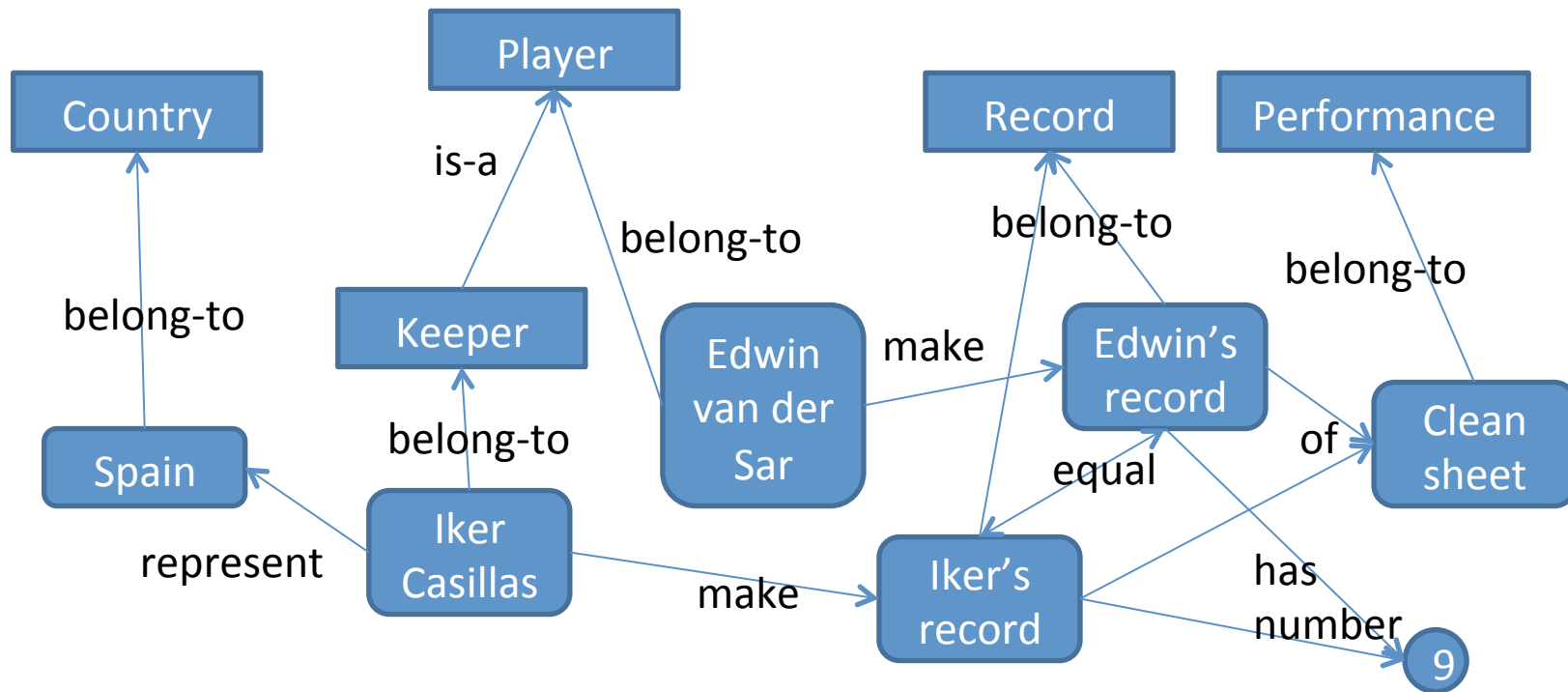
## How about Primary Key

- RDF is NOT expressive enough to represent primary key
- We need OWL (Web Ontology Language) for that
- Example with Friend Of a Friend (FoaF) ontology
  - foaf:OnlineAccount **owl:hasKey**  
(foaf:accountName  
foaf:accountServiceHomepage)

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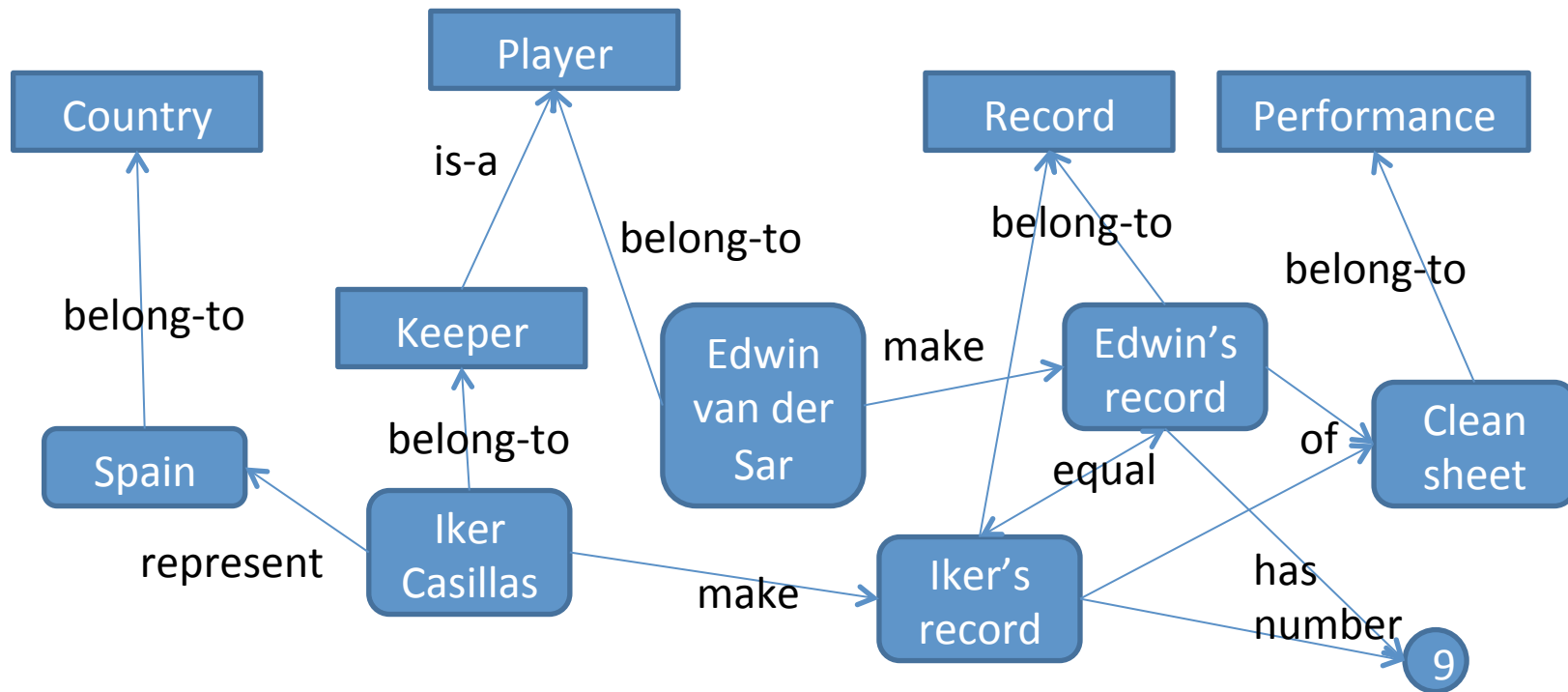
# Semantic Network



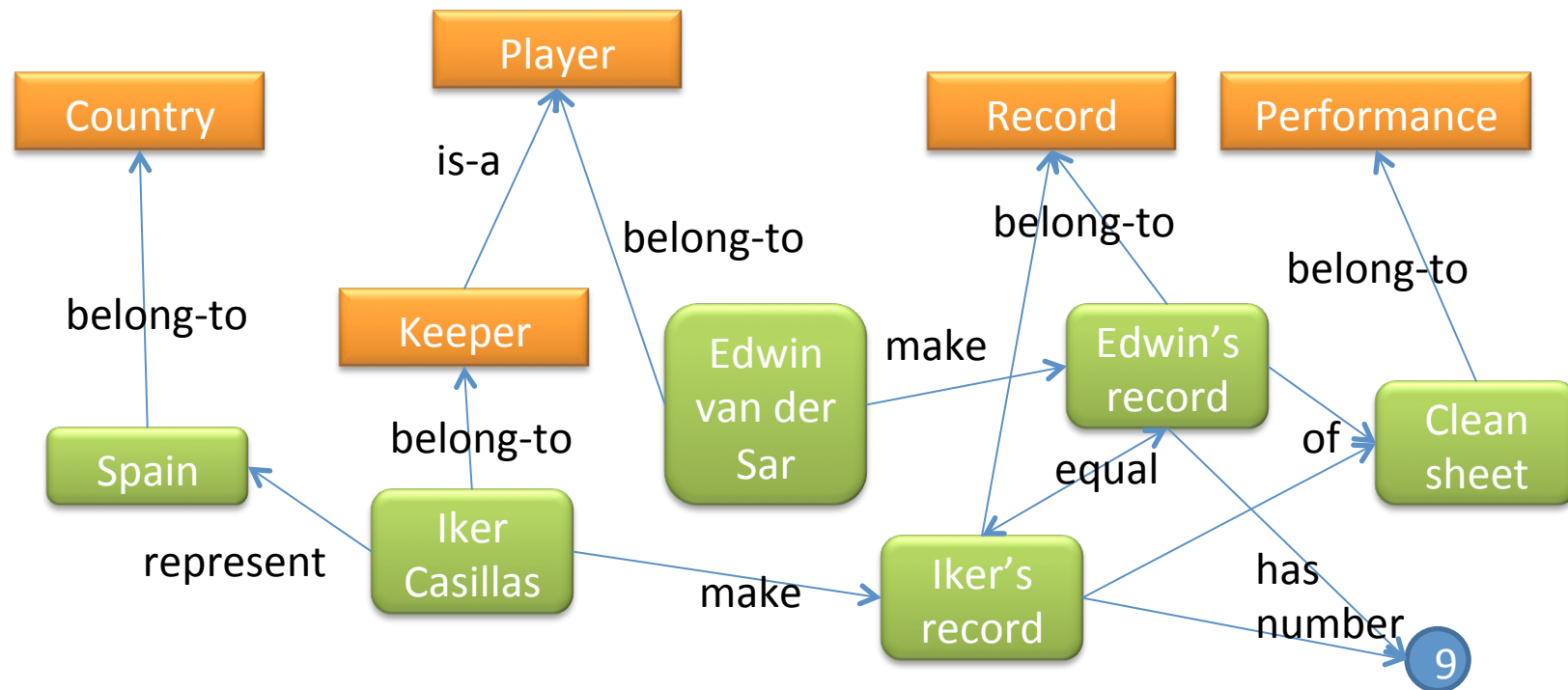
# Separating Concepts and Individuals

- In semantic networks, boxes can be concepts and individuals
- In ontologies, concepts and individuals are quite different things
  - An individual is interpreted as a domain element
    - E.g. “Iker Cassilas” is an individual person in the domain
  - A concept is interpreted as a set of domain elements
    - E.g. “Keeper” is the set of all keepers in the domain, including “Iker Cassilas”
  - Of course, whether a box is a concept or individual depends on the **granularity** of the domain
    - E.g. “cat” can be an individual if the ontology is about different species of “animal”
    - “cat” can be a concept if the ontology is about many individual cats, your cats, my cats, etc.

# Semantic Network



# Separating Concepts and Individuals

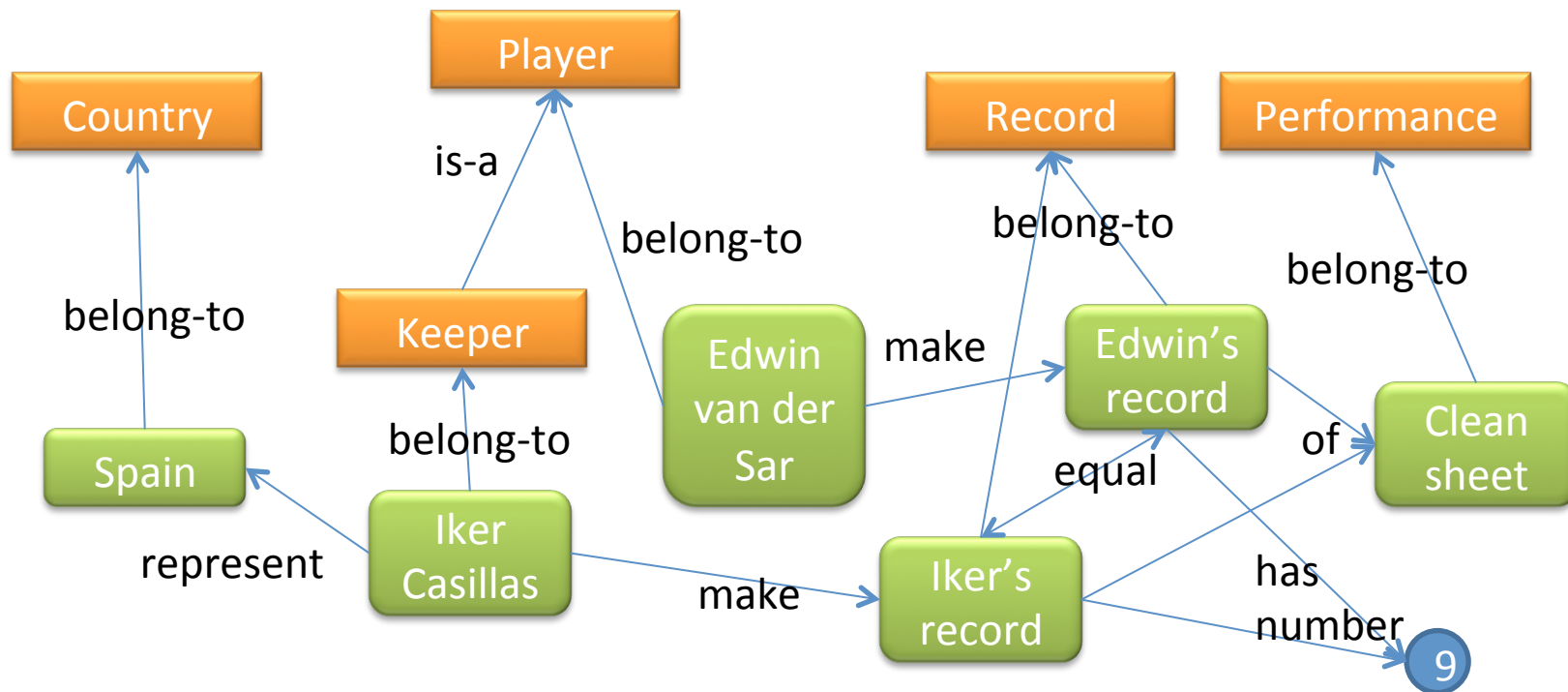


# Identifying Concept/Property Subsumption and Individual Classifications

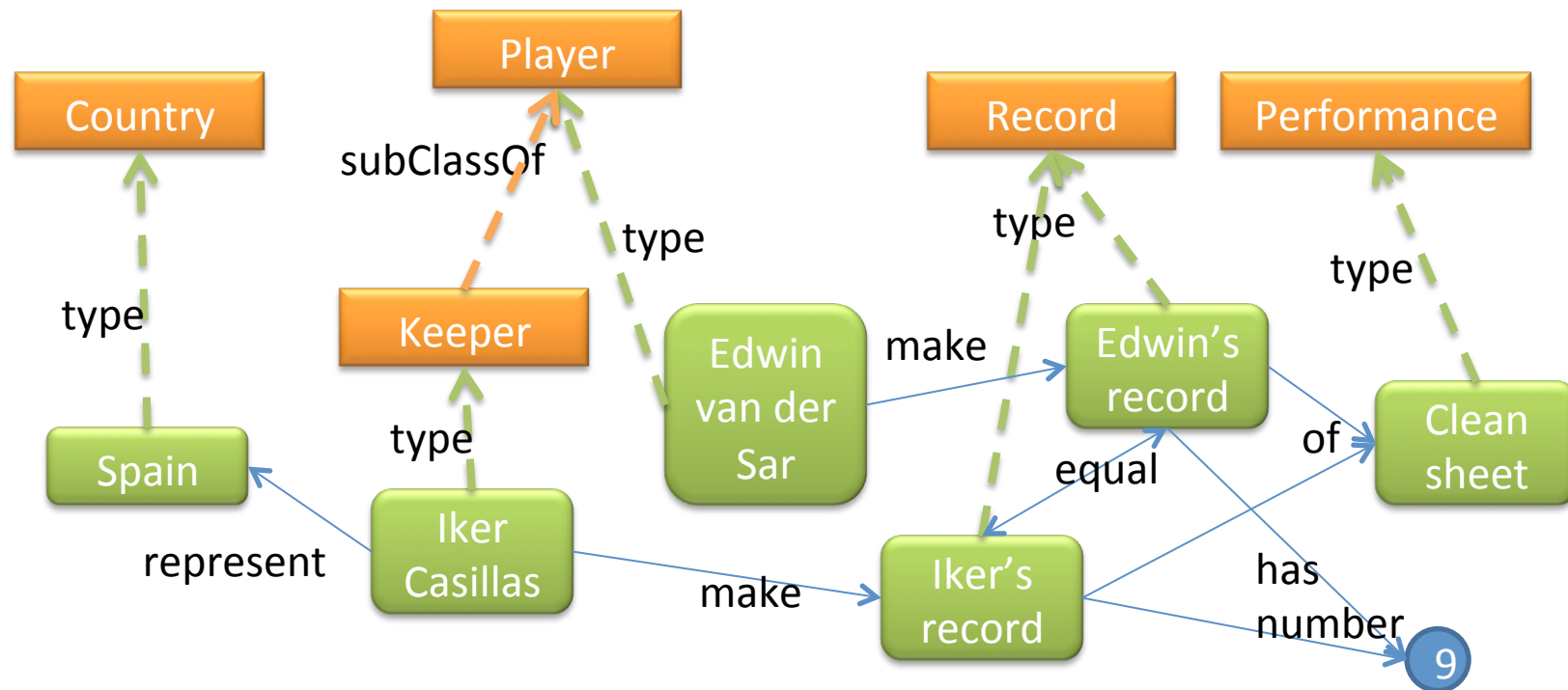
- In Semantic Networks, edges can be domain properties or predefined properties in RDF/OWL, such as
  - subClassOf, subPropertyOf and type
- An individual  $x$  is an instance of a concept  $C$  if  $x$  is interpreted as an element of the set that  $C$  represents
- A concept  $A$  is a **sub-concept** of a concept  $B$  if every instance of  $A$  is an instance of  $B$ 
  - E.g. every keeper is also a player, “Iker Casillas” is a “Keeper”,
  - “Keeper” is a sub-concept of “Player” implying that “Iker Casillas” is a “Player”
- A property  $R$  is a **sub-property** of a property  $S$  if every instance of  $R$  is an instance of  $S$



# Semantic Network



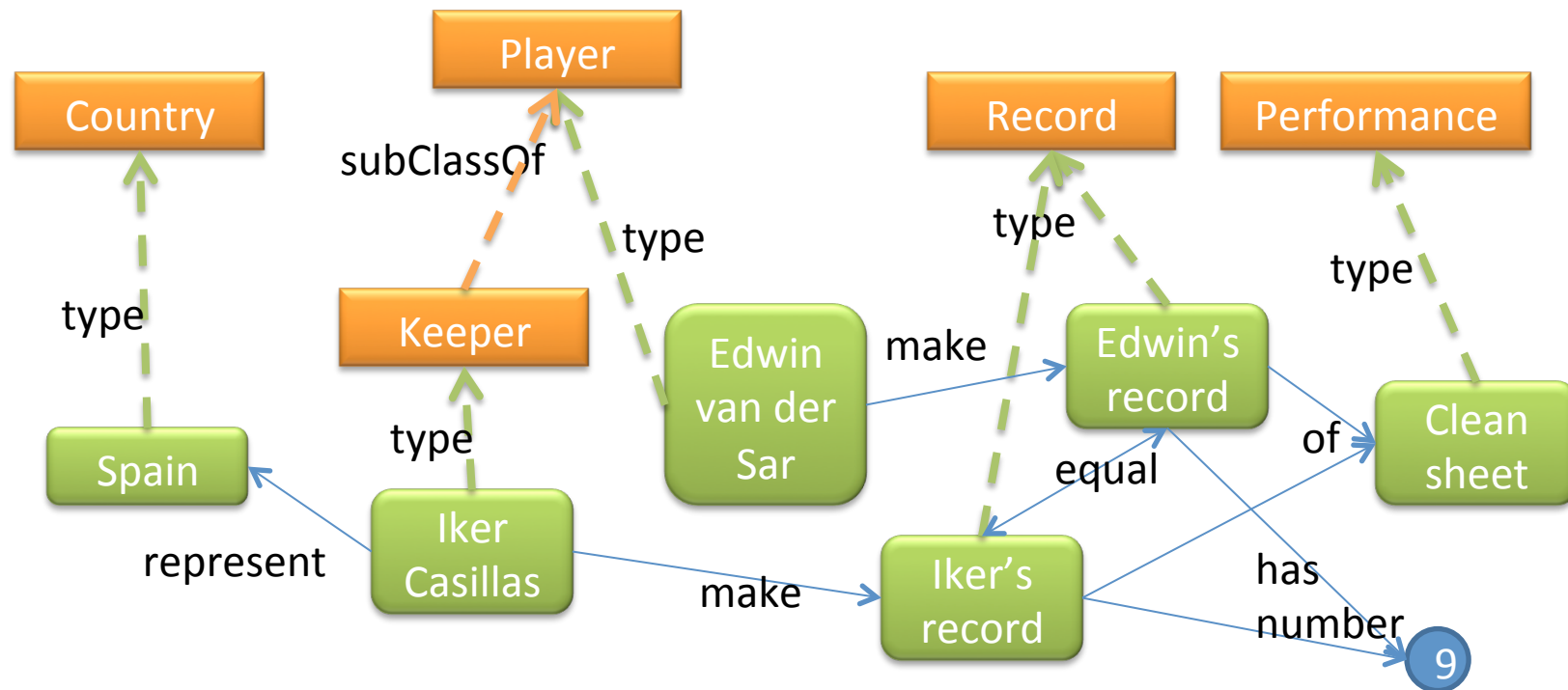
# Identifying Concept/Property Subsumption and Individual Classifications



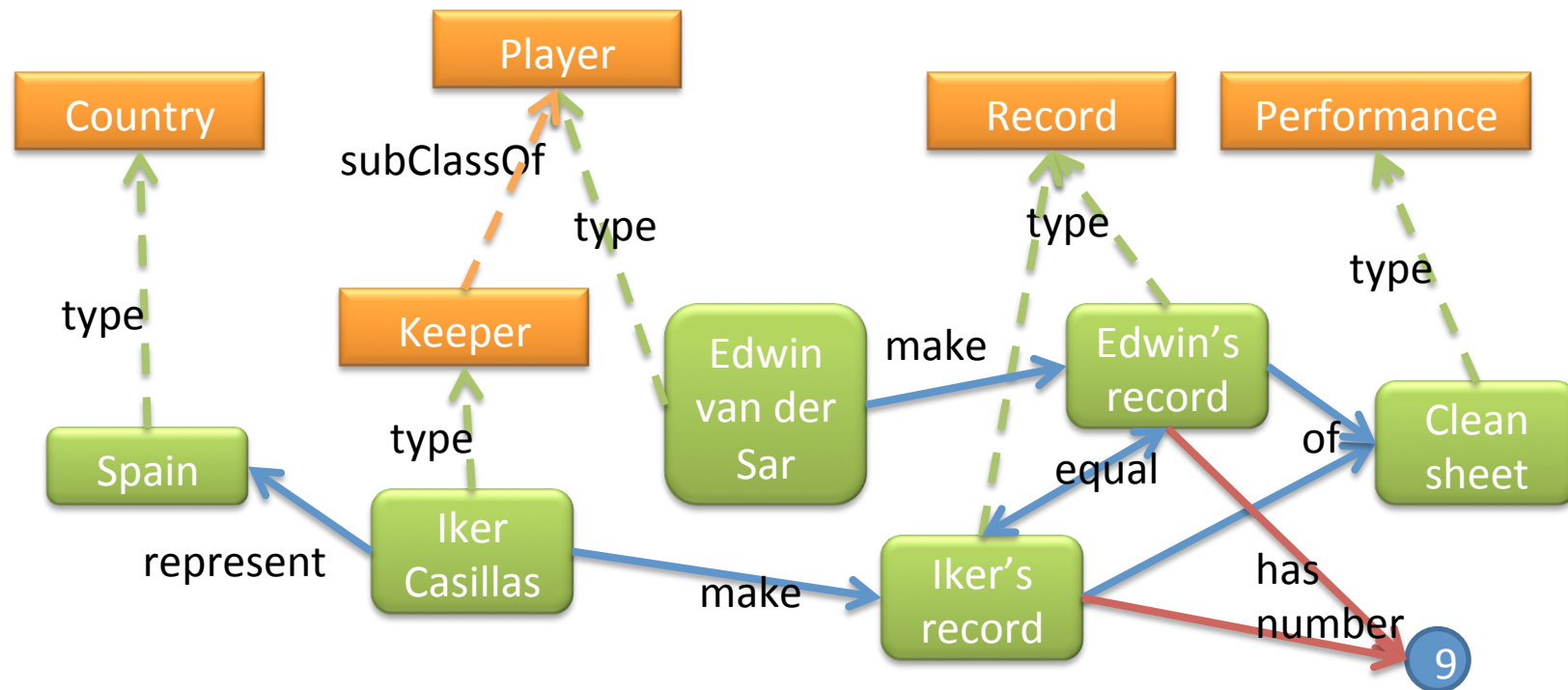
# Identifying Object Properties and Datatype Properties

- **Object properties** represent relations between two individuals
  - E.g. “Iker Casillas” and “Spain” are both individuals, hence Iker Casillas “represents” Spain is an object property.
- **Datatype properties** represent relations between an individual and a datatyped value
  - Data value includes numbers, dates, strings, etc.
  - E.g. “Iker’s record” is an individual, “9” is an integer, hence Iker’s record “has number” 9 is a datatype property.

# Semantic Network



# Identifying Object Properties and Datatype Properties

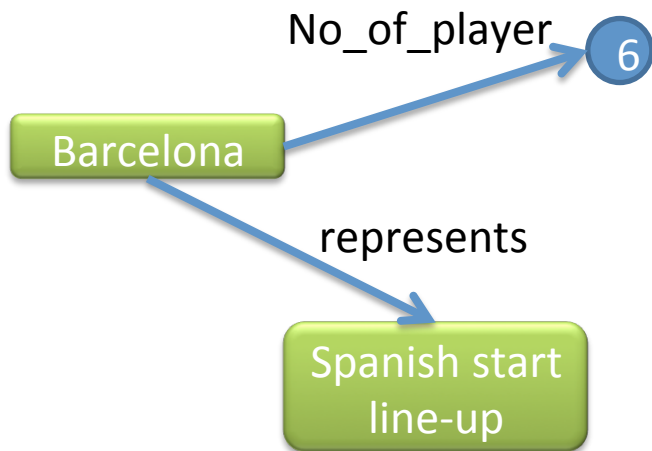


# Constructing the Ontology

1. Adding concepts
  - E.g. Country, Keeper, Player, Record, Performance
2. Adding Object and datatype properties
  - E.g. represents, make, equal, etc., has\_number, etc.
  - Domain and range
    - Domain of a property is a concept
      - E.g. Domain(represents) = Player
    - Range of an object property is a concept
      - E.g. Range(represents) = Country
    - Range of a datatype property is a datatype
      - E.g. Range(has\_number) = Integer
    - Based on the types of subjects and objects of relations
3. Adding individuals
  - E.g. spain, Iker\_Casillas, Iker's\_record, etc.
4. Adding individual relations and datatype property values
  - E.g. represents(Iker\_Casillas, spain), make(Iker\_Casillas, Iker's\_record), has\_number(Iker's\_record, 9)

# A Process of Refinement

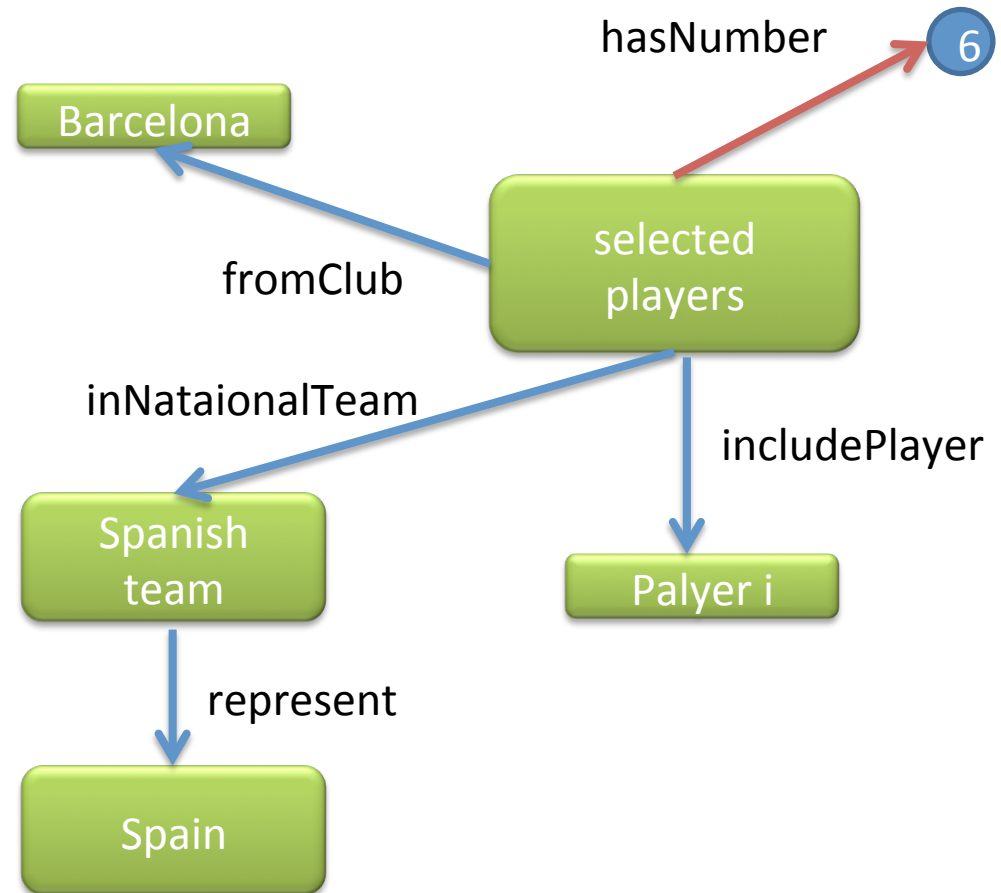
- The procedure of constructing an ontology is also a procedure in which you examine and refine your semantic networks!
- A typical example: multi-entity relationships
  - E.g. *“Six players from Barcelona were in the Spanish starting line-up”*
    - This is a complex relationship involving a “Country’s team”, a “club team”, and “6” players
  - In semantic networks, one may draw a figure like this or similar:



- This is not semantically precise:
  - Barcelona has 6 players?
    - No, it has 6 players in the Spanish start line-up
  - Barcelona represents Spain?
    - No, its 6 players represent Spain in the start line-up
- This relationship makes sense only when you take all these entities into account!

# A Process of Refinement

- An alternative representation  
– there could be others
- Constructing ontology helps you re-evaluate and refine your semantic network.





# Practical



- Revisit your semantic networks and see
  - how to construct OWL ontologies accordingly
- How to construct OWL ontologies
  - ontology editors  $\leftrightarrow$  OWL abstract syntax
  - using OWL API

# Summary

- RDF and other modelling mechanisms
  - Modern version of semantic network, with formal syntax and semantics
  - Can represent data and foreign keys in relational data model
    - but not primary key
- OWL provides much expressiveness that RDF does not have
- Understand how to build OWL ontologies from semantic networks

