World models
the practice
(T2MP)

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- **Types of world models**
- Types of world model translation
- Translation across levels of formalization
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- Translation syntax from/to semantics
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Types of world models

Intuition (Language, informal, semi-formal, Logical) There are three types of languages and, correspondingly, three types of world models:

- **Informal world models**, namely world models where the grammar of the language is defined informally, for instance, in natural language and without using production rules.
- **Semi-formal models,** namely world models where the grammar of the language is formally defined.
- **Formal (Logical) world models**, namely world models where where the grammar as well as the interpretation of the language are formally defined.

Types of world models

Observation (Formal, semi-formal, informal world model). A formal world model is defined as $W = \langle L_a, D, I_a \rangle$. In informal and semi-formal world-models the interpretation function and domain of interpretation are left implicit, assuming speaker/listener coincidence of their mental analogical mental representations.

Observation (Semi-formal world models). Semi-formal world models have been defined in computer science using simplified languages, with low expressiveness and exploiting the intrinsic intuitiveness of graph-based languages. In most case the syntax of these languages is formally defined. But not the meaning of the terms of the alphabet.

Why informal world models

Observation (Why informal languages) We have the following.

Advantages:

- Everybody knows them.
- In Computer Science they are typically used when writing early requirements, e.g., to be shown to customers.
- Now also used in the interactions with ChatBots (LLMs).

Disadvantages:

- Semantics are extremely ambiguous
- High probability of misunderstanding
- Cannot be used by themselves in high value applications

Why semi-formal formal world models

Observation (Why semi-formal languages) We have the following.

Advantages:

- Semi-formal languages are typically used in Software Engineering when writing advanced requirements.
- They decrease the level of ambiguity and are very effective in the collaborative work among Software Engineers.
- They can also be used in automatic code generation.

Disadvantages:

- Problems arise because of some level of semantic ambiguity in the alphabet
- Can be used by themselves in most applications
- Cannot be used by themselves in very high value applications (e.g., safety- or security critical applications)

Why logical world models

Observation (Why logical languages) We have the following.

Advantages:

- Logical languages have two main uses:
- (i) The specification of highly critical SW and HW (e.g., safety or security critical systems) and
- (ii) the implementation of reasoning systems, typically AI systems, capable of computing consequences from what is known.

Disadvantages:

- Hard to learn, require specialized competences
- Impossible to understand for a person who is not specifically trained.

Types of world models (examples)

Example 3 (Language, informal, semi-formal, logical) We have the following examples

- Informal languages: all natural languages;
- Semi-formal languages: DB relational language, the ER and EER notation, KGs, lexicons;
- Logical languages: the languages used in logics EG, ETG.

Observation (Language, informal, semi-formal, logical) Sometimes informal languages are used to explain to non-experts the content of a semantic or linguistic representation.

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World model Translation

Intuition (translation across world models). There are at least three types of translation, that is:

- **Translation across levels of formalization:** Increasing / decreasing the level of formalization across world models.
- **Translation across languages:** Change of notation across world models at the same level of formalization.
- **Translation syntax from/ to semantics:** mapping syntax to/from semantics inside the same world model.

Increasing /decreasing the level of formalization

Intuition (Increasing the level of information). In SW Engineering, it is most often the case that one follows a three step approach:

- Generate an informal model, mainly in natural language (e.g., the requirements), easily understood by the user.
- Generate a semi-formal model (e.g., and ER diagram) to design the logical architecture.
- Generate a formal model, when needed, to validate specific properties of the model.

Intuition (Decreasing the level of information). This is often used to explain a (semi-)formal model to non experts.

Increasing /decreasing the level of formalization (continued)

We have the following possible six cases:

- Informal-to-semiformal world models
- Semiformal-to-formal world models
- Informal-to-formal world models
- Formal-to-semiformal world models
- Semiformal-to-informal world models
- Formal-to-informal world models

Change of notation

Intuition (Change of notation). The most common situation is the translation between world models at the same level of formality but different notation and/or expressiveness. The main motivation is to move to a notation which is more suitable for the problem to solve.

Example (Change of notation).

- Complex NL from/to simpler NL (e.g., a pseudo-natural language)
- ER models from/to EER models (discover common etypes)
- DBs from/to KGs(more flexible)
- ER models from/to KGs (the second can be implemented)
- N-ary KGs from/to binary KGs
- Translations between any two logics

Correctness / Completeness of translation

Observation (Truth / Falsity). The notions of Truth and Falsity are meaningful only if made with respect to a formalized reference model, and interpretation function. For the other types of models, the assertion

$a \in L_a$ is **True** if the fact f = $I_a(a) \in M$, **False** otherwise

can only be evaluated qualitatively «guessing» the intended model and the interpretation function, which are assumed to formalize the commonsense understaning of words.

Observation (Correcteness and completeness). As for truth and falsity, correctness and completeness are reasoned about by commonsense.

Correctness / Completeness of translation

Intuition (Correctness and completeness of translation across world models). For all types of translation, **the facts** which are **True** in the source world model must also be **True** in the target world model, and dually for **False** facts. That is, a translation must preserve (informally, when formally is impossible)

correctness and **completeness**.

Syntax to/from semantics

Intuition (Syntax to/from semantics).

Syntax to semantics: used to provide (some level of) certification of the correctness /completeness of theory.

Semantics to syntax: used when one is provided an analogical representation and needs to generate a linguistic representation.

The most common case is the mapping from syntax to semantics.

Example (Mapping from/to syntax to/from semantics).

- Generate an explicit model of an informal or semi-formal world model
- Provide a linguistic description of a picture or movie

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Exercize 1 – An informal (NL) world model

Consider the following NL informal world model.

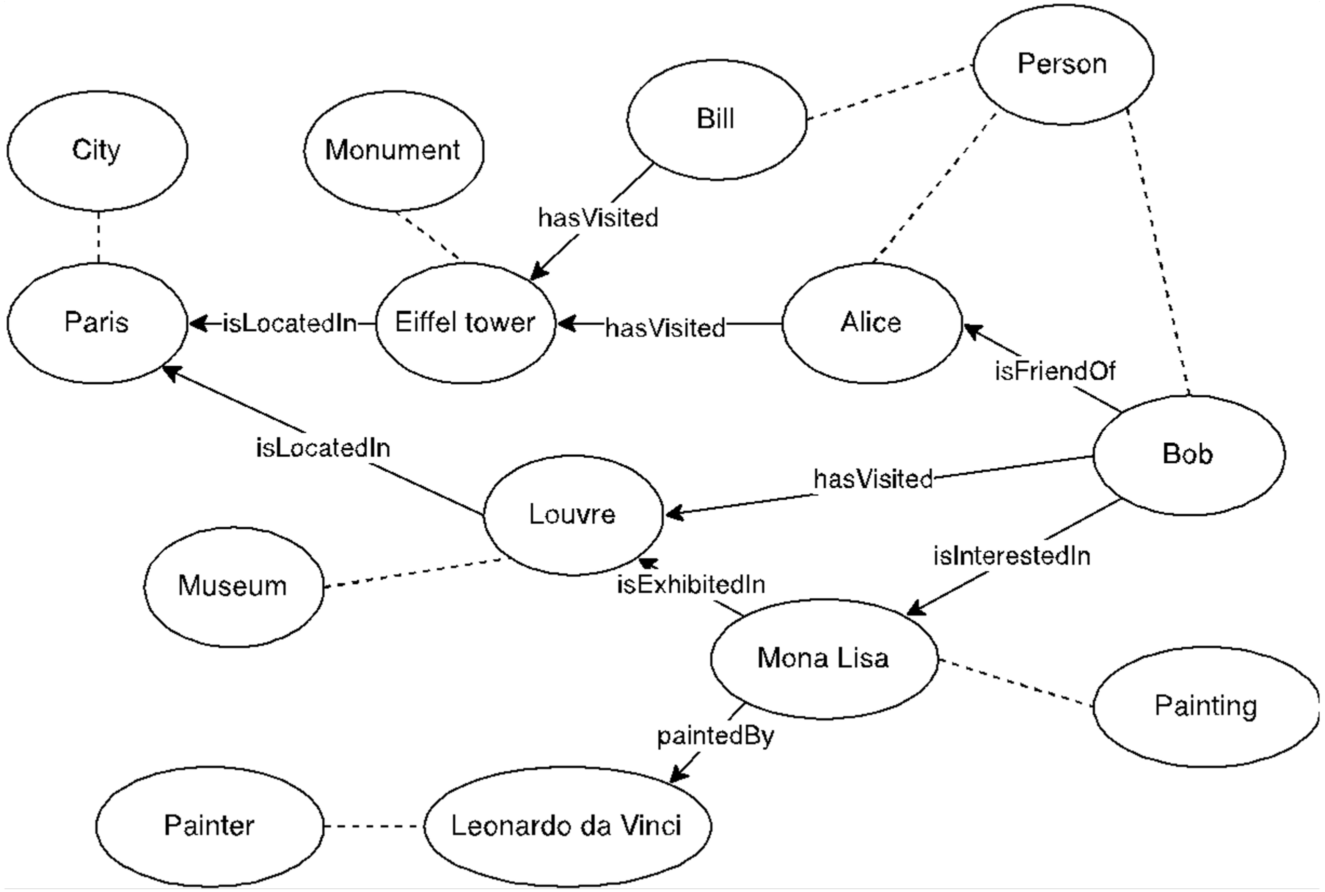
Bill and Alice went to Paris with Alice's friend Bob.
Bill and Alice visited the Eiffel Tower, one of the most visited monuments in Paris.

Instead, Bob was interested in the Mona Lisa, painted by painter Leonardo da Vinci, so he went to the Louvre, a famous museum in Paris

Exercize 1 – From informal (NL) to semi-formal (KG)

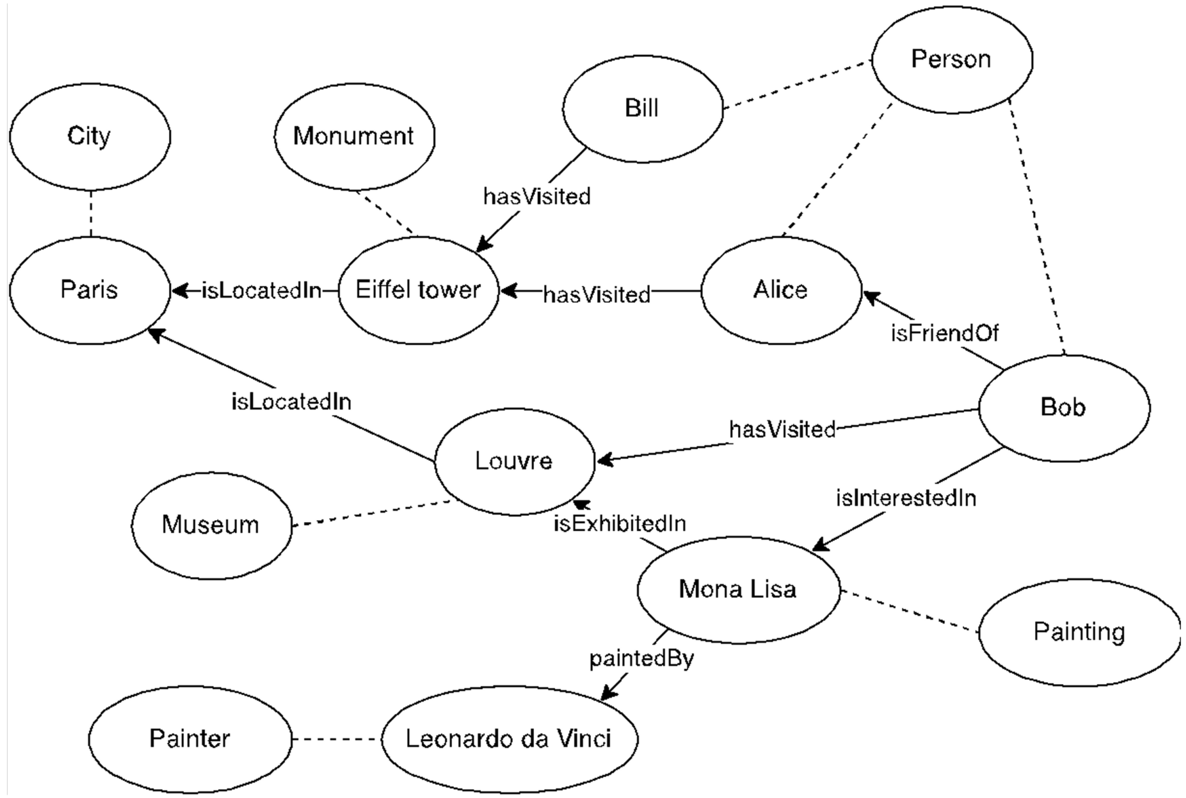
Bill and Alice went to Paris with Alice's friend Bob. Bill and Alice visited the Eiffel Tower, one of the most visited monuments in Paris.

Instead, Bob was interested in the Mona Lisa, painted by painter Leonardo da Vinci, so he went to the Louvre, a famous museum in Paris.



Exercize 1 – Semi-formal (KG) to formal (LoE)

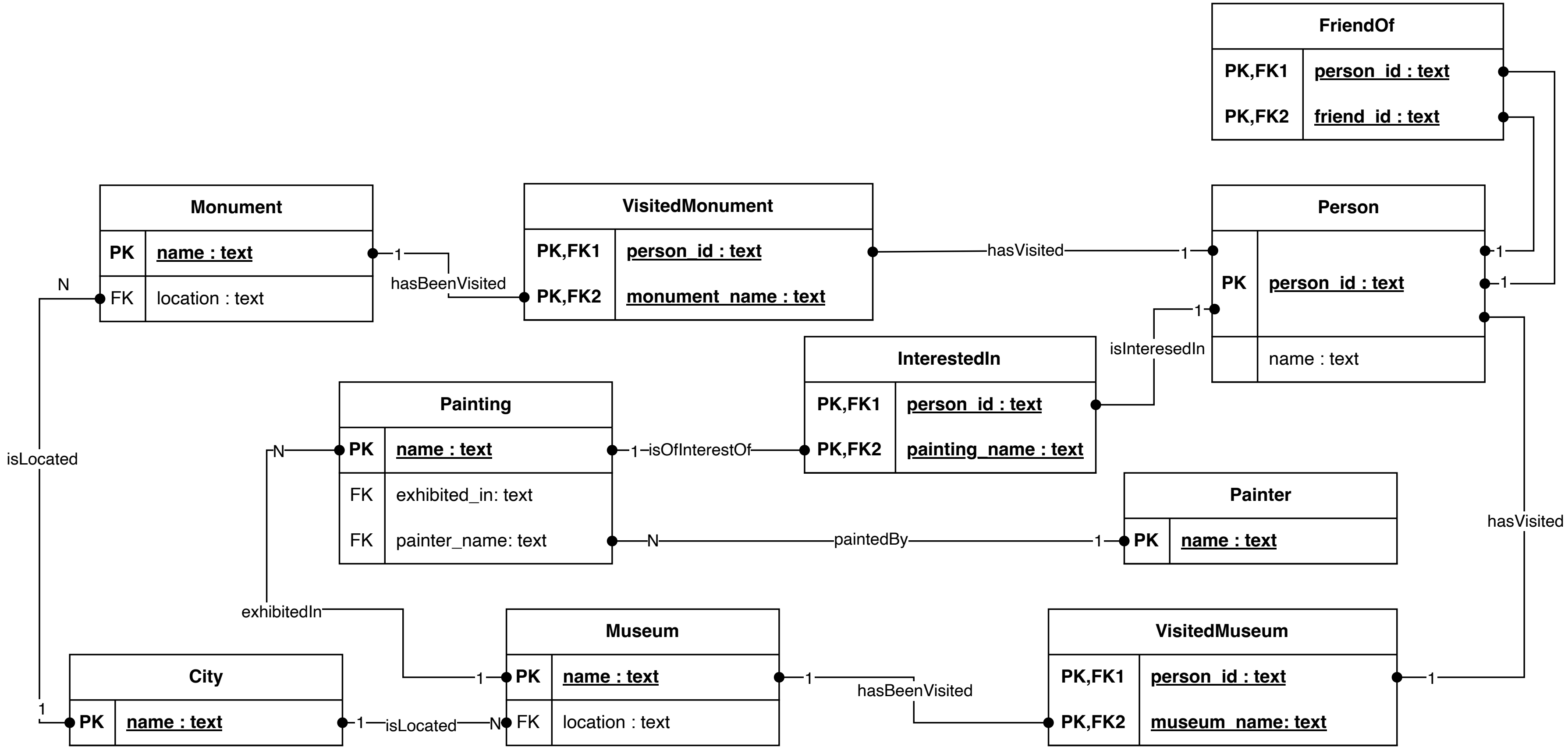
From the previously built KG, define a formal model using LOE.



$Person(Alice)$
$Person(Bob)$
$Person(Bill)$
$City(Paris)$
$Monument(Eiffel\ Tower)$
$Museum(Louvre)$
$Painting(MonaLisa)$
$Painter(Leonardo\ da\ Vinci)$
$isFriendOf(Bob, Alice)$
$hasVisited(Alice, Eiffel\ Tower)$
$hasVisited(Bill, Eiffel\ Tower)$
$hasVisited(Bob, Louvre)$
$paintedBy(Mona\ Lisa, Leonardo\ da\ Vinci)$
$exhibitedIn(Mona\ Lisa, Louvre)$
$interestedIn(Bob, Mona\ Lisa)$
$isLocatedIn(Eiffel\ Tower, Paris)$
$isLocatedIn(Louvre, Paris)$

Exercize 2 – a semi-formal (ER) Model

From this ER model, define the corresponding formal model using LOE.



Exercize 2 - Semi-formal (ER) to formal (LoE)

From the previous ER model, define a formal model using LOE.

There is no translation!

An ER model doesn't specify entities and,
therefore, cannot be formalized in LoE,
NOT EVEN PARTIALLY,
as LoE does not allow for
"Knowledge-level" assertions

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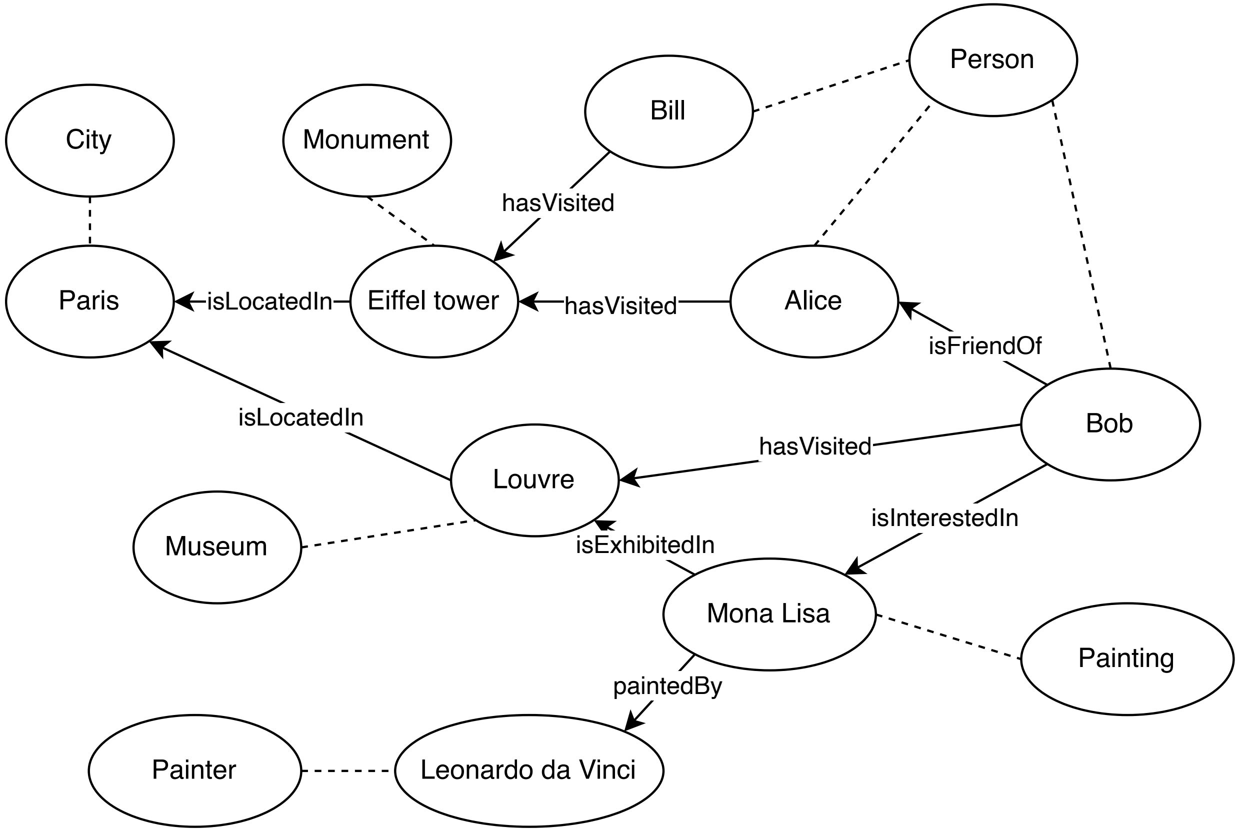
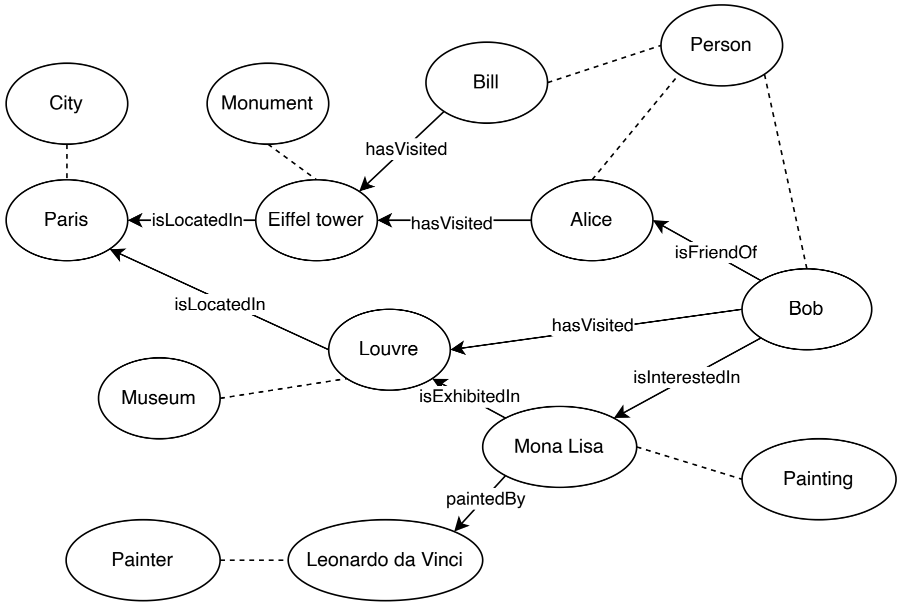
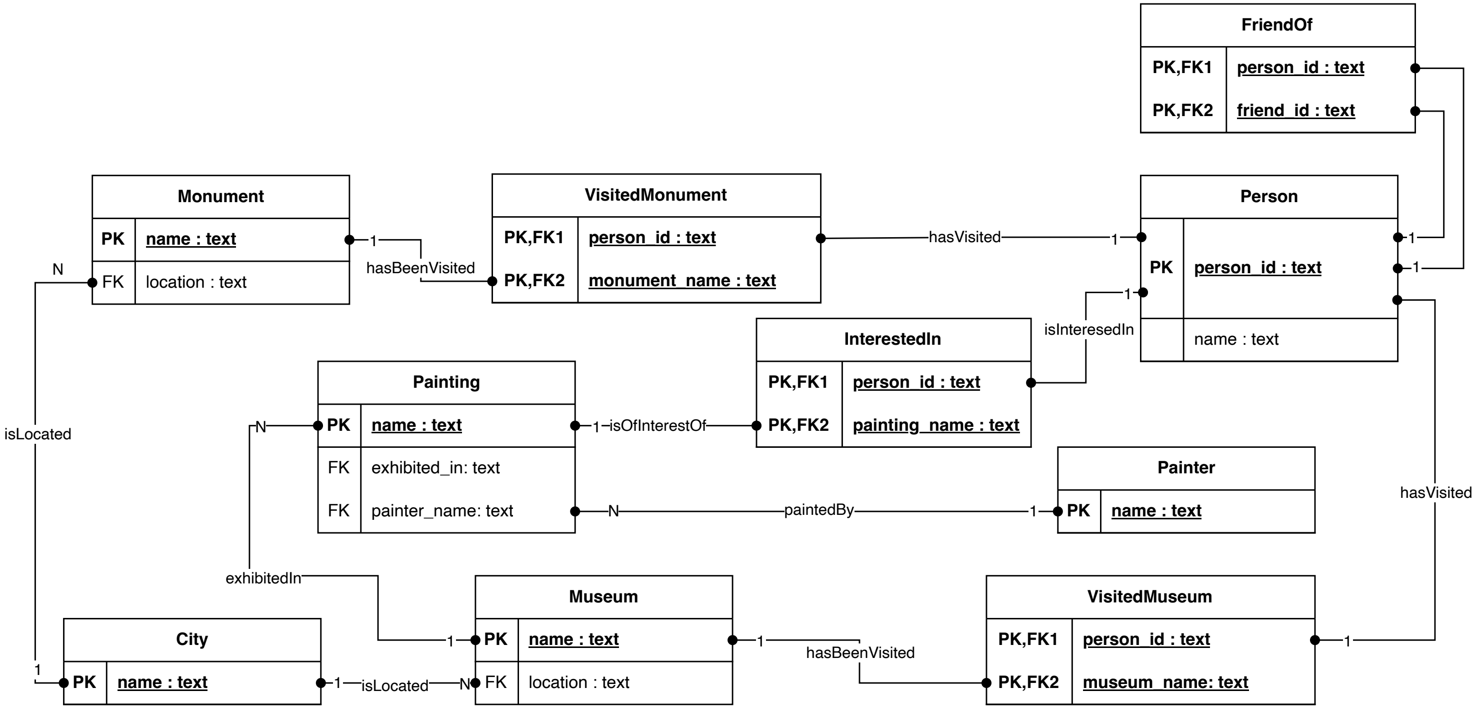
Exercize 3 – A semi-formal KG diagram



Exercize 3 – From KG to ER

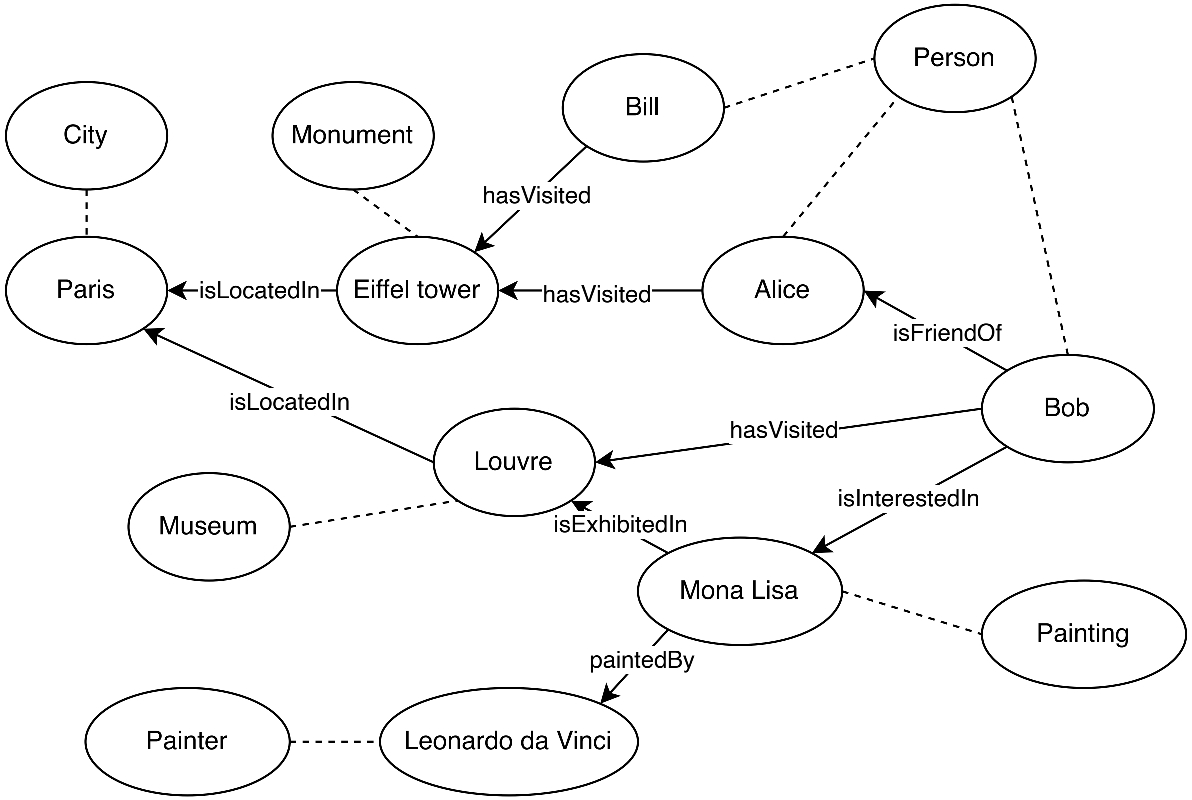
From the KG diagram just seen, build the corresponding ER model





Exercize 4 – From KG to DB

From the KG diagram just built, build the corresponding DB



Exercize 4 – From KG to DB

From the KG diagram just built, build the corresponding DB

Person

person_id	name
p_1	Bill
p_2	Alice
p_3	Bob

Painting

name	exhibited_in	painted_by
Mona Lisa	Louvre	Leonardo da Vinci

Monument

name	location
Eiffel Tower	Paris

Painter

name
Leonardo da Vinci

VisitedMonument

person_id	monument_name
p_1	Eiffel Tower
p_2	Eiffel Tower

VisitedMuseum

person_id	museum_name
p_1	Louvre

City

name
Paris

Interest

person_id	painting_name
p_3	Mona Lisa

Friend

person_id	friend_id
p_2	p_3

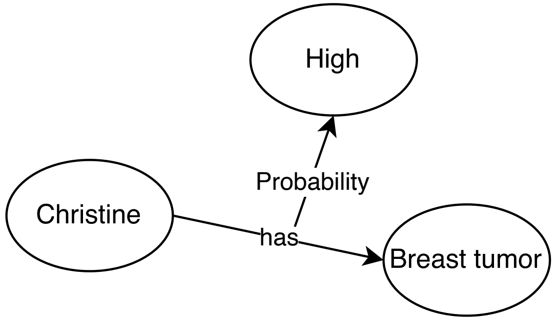
Museum

name	location
Louvre	Paris

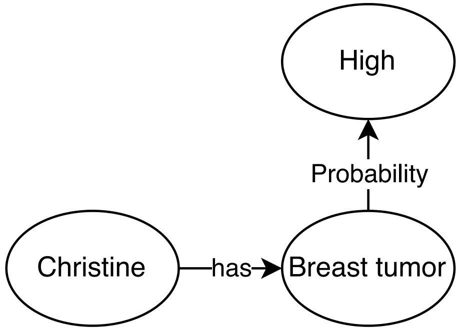
Exercize 5 – From an (n-ary KG) relation to a (binary KG) relation

"Christine has breast tumor with high probability"

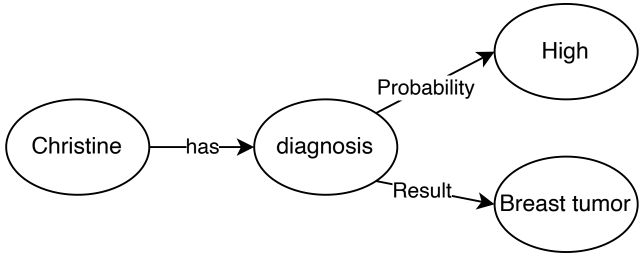
The idea is to achieve this:



Wrong, in this case every instance of breast tumor has high probability.



By adding a new entity "diagnosis" we can represent that christine has breast tumor with high probability by using only binary realtions.

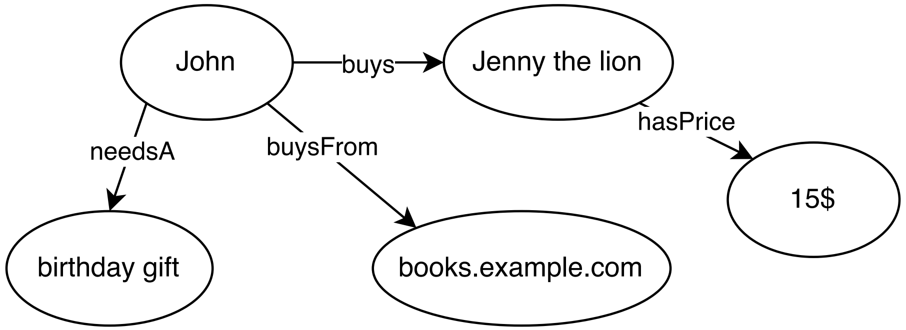


Exercize 6 – From am (N-ary KG) relation with no distinguished participant to a (binary KG) relation

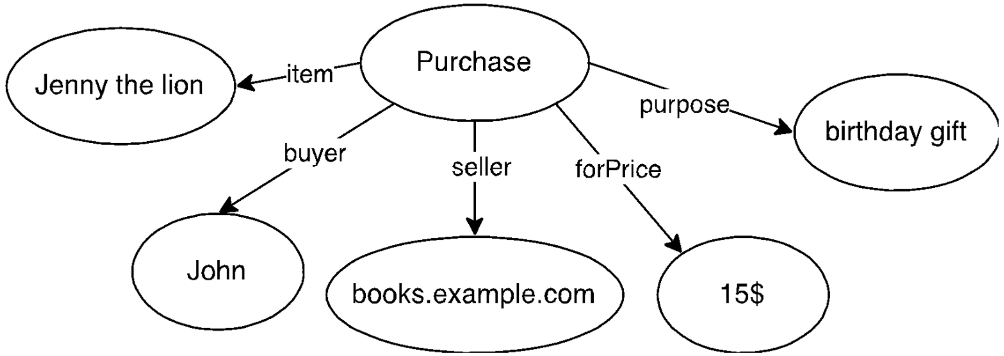
"John buys a "Lenny the Lion" book from books.example.com for $15 as a birthday gift"

In this case, there is a relation between John, the "Lenny the Lion" book he buys, and between John and the website where he has bought the book. Then there is also to represent how much he has paid and what was the purpose of the purchase.

Wrong, with this representation we are not saying that John is buying that specific book on that website, and neither for which price or for what purpose. We just know that the book as a price of 15$, that John has bought it (for some price), and that he buys from books.example.com.



To represent the above sentence in the correct way we need to add a new entity "Purchase" that ties together all the other elements in a single event, representing this way that John has purchased a specific item from a specific seller at a certain price and for a specific purpose.



Exercize 7,8 – From an (n-nary KG) relation to LoE

Build the LoE theory describing the two n-ary graphs defined in the previous two exercises

Exercize 7,8 – From an (n-nary KG) relation to LoE

Build the LoE theory describing the two n-ary graphs defined in the previous two exercises

$hasDiagnosis(Christine, Diagnosis\#1)$
$hasResult(Diagnosis\#1, Breast\ Cancer)$
$hasProbability(Diagnosis\#1, High)$

$Event(Purchase\#1)$
$hasBuyer(Purchase\#1, John)$
$hasSeller(Purchase\#1, books.example.com)$
$hasPrice(Purchase\#1, 15\$)$
$has\mathrm{Item}(\mathrm{Purchase\#1, Jenny\ the\ Lion})$
$hasPurpose(Purchase\#1, Birthday\ gift)$

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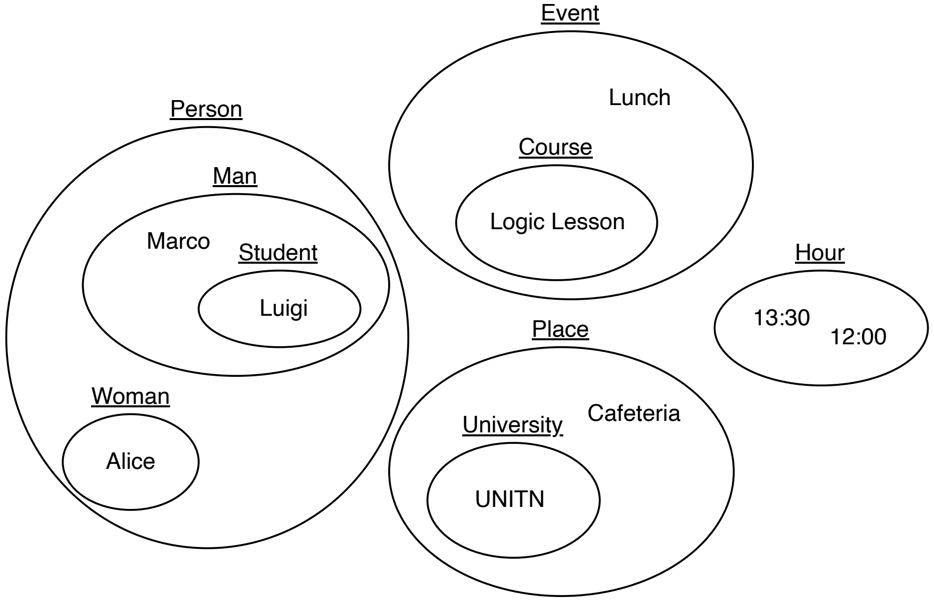
Exercize 9 - Correctness



$< Alice, Luigi > \in isMotherOf$

$< Marco, Luigi > \in isFatherOf$

$< Luigi, UNITN > \in studiesAt$

$< Luigi, Logic\ Lesson > \in isAttending$

$< Luigi, Cafeteria > \in hasLunchIn$

$< Lunch, 12:00 > \in startAt$

$< Lofic\ Lesson, 13:30 > \in startAt$

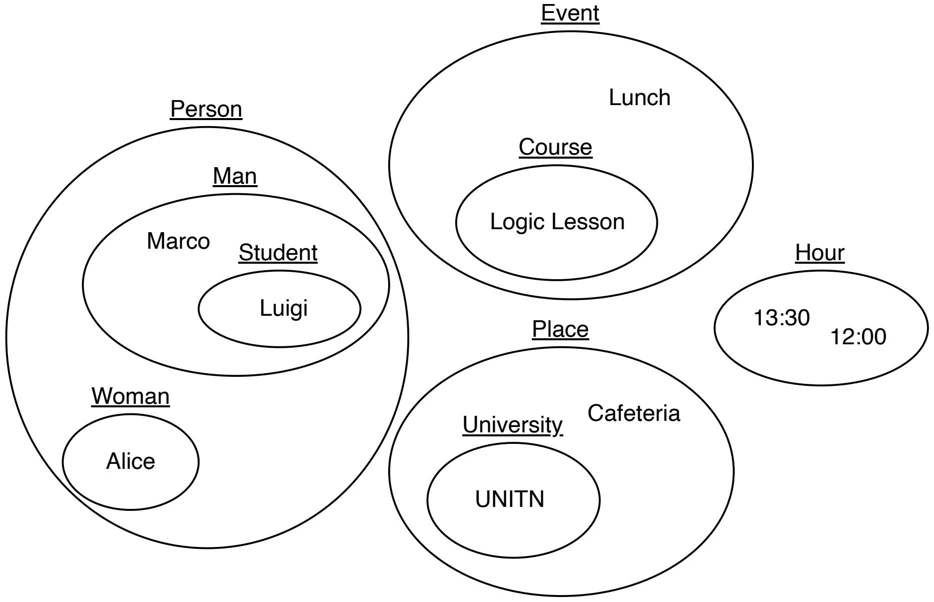
Considering the intended model on the left and the interpretation function below, is the following a theory correct?

$I_e(Marco) = Marco$
$I_e(Luigi) = Luigi$
$I_e(Alice) = Alice$
$I_E(Woman) = Woman$
$I_E(Student) = Student$
$I_E(Man) = Man$
$I_O(motherOf) = motherOf$
$I_O(fatherOf) = fatherOf$

$Man(Marco)$
$Student(Luigi)$
$Woman(Alice)$
$motherOf(Alice, Luigi)$
$faterOf(Marco, Luigi)$

Yes, as every assertion of the theory is true in the model.

Exercize 10 - Correctness



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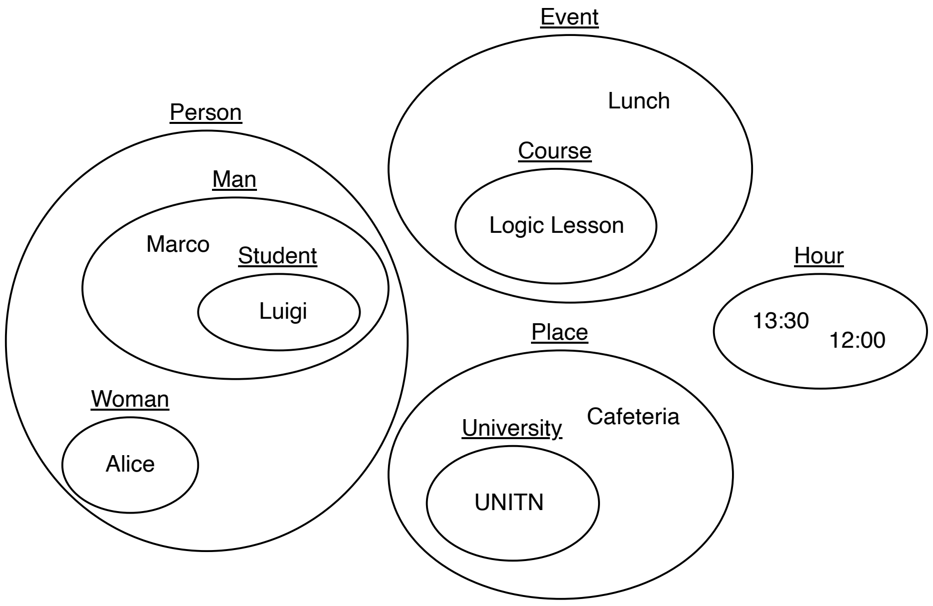
$$I_E(Student) = Student$$
$$I_E(Man) = Man$$
$$I_O(motherOf) = motherOf$$
$$I_O(fatherOf) = fatherOf$$

$$Student(Marco)$$
$$Man(Luigi)$$
$$Woman(Alice)$$
$$motherOf(Alice, Luigi)$$
$$faterOf(Marco, Luigi)$$

No, because Marco is not a student.

Exercize 11 - Correctness



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$< Luigi, UNITN > \in studiesAt$

$< Luigi, Logic\ Lesson > \in isAttending$

$< Luigi, Cafeteria > \in hasLunchIn$

$< Lunch, 12:00 > \in startAt$

$< Lofic\ Lesson, 13:30 > \in startAt$

Considering the intended model on the left and the interpretation function below, is the following a theory correct?

$I_e(Marco) = Luigi$
$I_e(Luigi) = Marco$
$I_e(Alice) = Alice$

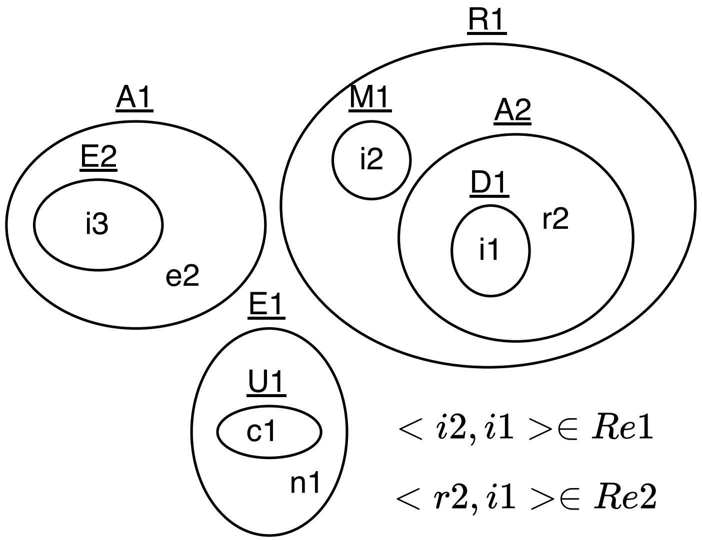
$I_E(Woman) = Woman$
$I_E(Student) = Student$
$I_E(Man) = Man$

$I_O(motherOf) = motherOf$
$I_O(fatherOf) = fatherOf$

$Student(Marco)$
$Man(Luigi)$
$Woman(Alice)$
$motherOf(Alice, Marco)$
$faterOf(Luigi, Marco)$

Yes, as by the interpretation function «Marco» in the theory is «Luigi» in the model, and «Luigi» in the theory is «Marco» in the model.

Exercize 12 - Correctness



$< i2, i1 > \in Re1$

$< r2, i1 > \in Re2$

$< i1, i3 > \in Re3$

$< i1, c1 > \in Re4$

$< i1, e2 > \in Re5$

Considering the intended model on the left and the interpretation function below, is the following a theory correct?

$I_e(L) = i1 \quad I_E(U) = E2$

$I_e(N) = i3 \quad I_E(S) = D1$

$I_e(G) = c1 \quad I_E(C) = U1$

$I_O(sA) = Re3$

$I_O(iA) = Re4$

$S(L)$

$sA(L, N)$

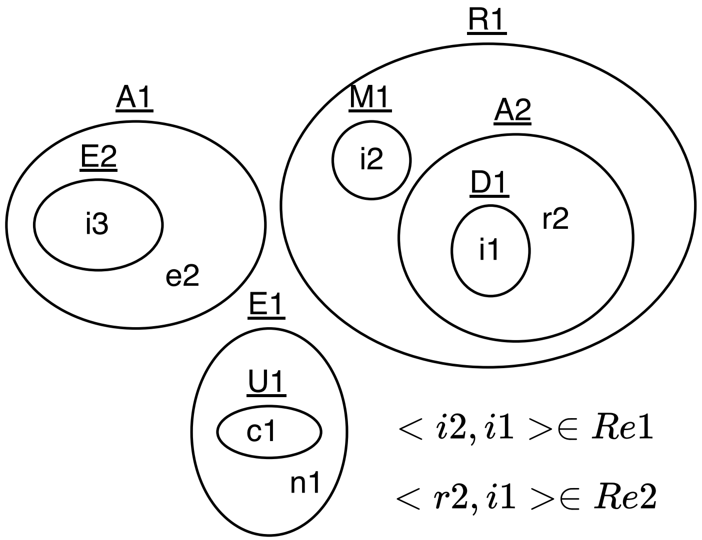
$U(N)$

$iA(L, G)$

$C(G)$

Yes, the model is actually the same as before, without the hours, and the theory has been abbreviated to single letters.

Exercize 13 - Correctness



$< i2, i1 > \in Re1$

$< r2, i1 > \in Re2$

$< i1, i3 > \in Re3$

$< i1, c1 > \in Re4$

$< i1, e2 > \in Re5$

Considering the intended model on the left and the interpretation function below, is the following a theory correct?

$I_e(L) = i1$ $\quad I_E(U) = E2$

$I_e(N) = c1$ $\quad I_E(S) = D1$

$I_e(G) = i3$ $\quad I_E(C) = U1$

$I_O(sA) = Re3$

$I_O(iA) = Re4$

$S(L)$

$sA(L, N)$

$U(N)$

$iA(L, G)$

$C(G)$

No, as $< i1, c1 > \notin Re3$ and $< i1, i3 > \notin Re4$.

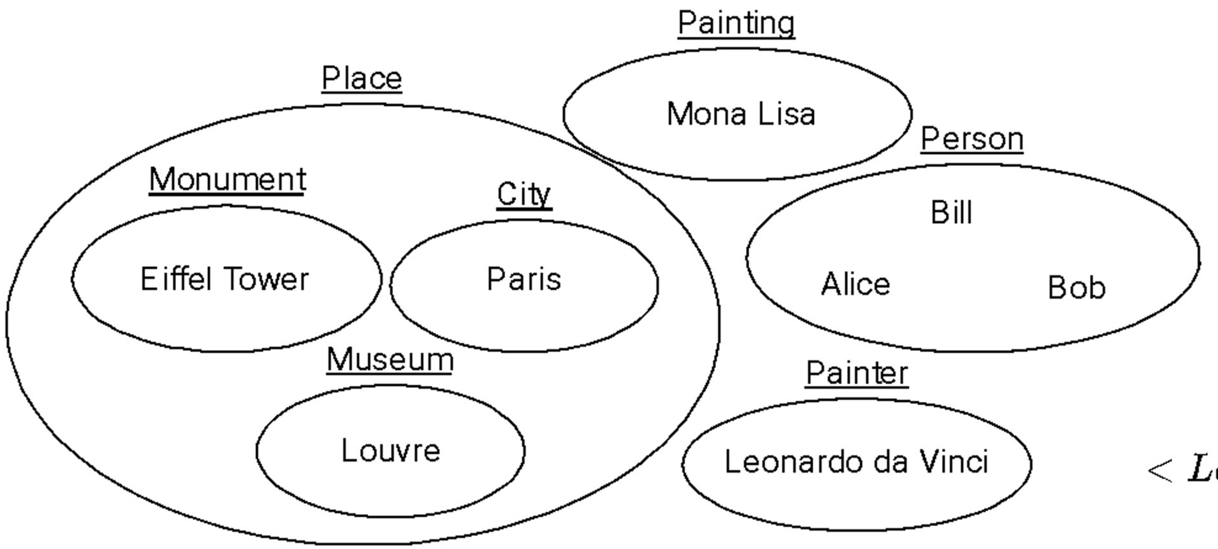
Exercize 14 – A LoE Theory

$Person(Alice)$
$Person(Bob)$
$Person(Bill)$
$City(Paris)$
$Monument(Eiffel\ Tower)$
$Museum(Louvre)$
$Painting(MonaLisa)$
$Painter(Leonardo\ da\ Vinci)$

$isFriendOf(Bob, Alice)$
$hasVisited(Alice, Eiffel\ Tower)$
$hasVisited(Bill, Eiffel\ Tower)$
$hasVisited(Bob, Louvre)$
$paintedBy(Mona\ Lisa, Leonardo\ da\ Vinci)$
$exhibitedIn(Mona\ Lisa, Louvre)$
$interestedIn(Bob, Mona\ Lisa)$
$isLocatedIn(Eiffel\ Tower, Paris)$
$isLocatedIn(Louvre, Paris)$

Exercize 14 – From syntax to semantics

From the previously built formal model using LOE, make explicit the intended model using set theory.



$$< Bill, Eiffel\ Tower > \in hasVisited$$

$$< Alice, Eiffel\ Tower > \in hasVisited$$

$$< Bob, Alice > \in isFriendOf$$

$$< Eiffel\ Tower, Paris > \in isLocatedIn$$

$$< Louvre, Paris > \in isLocatedIn$$

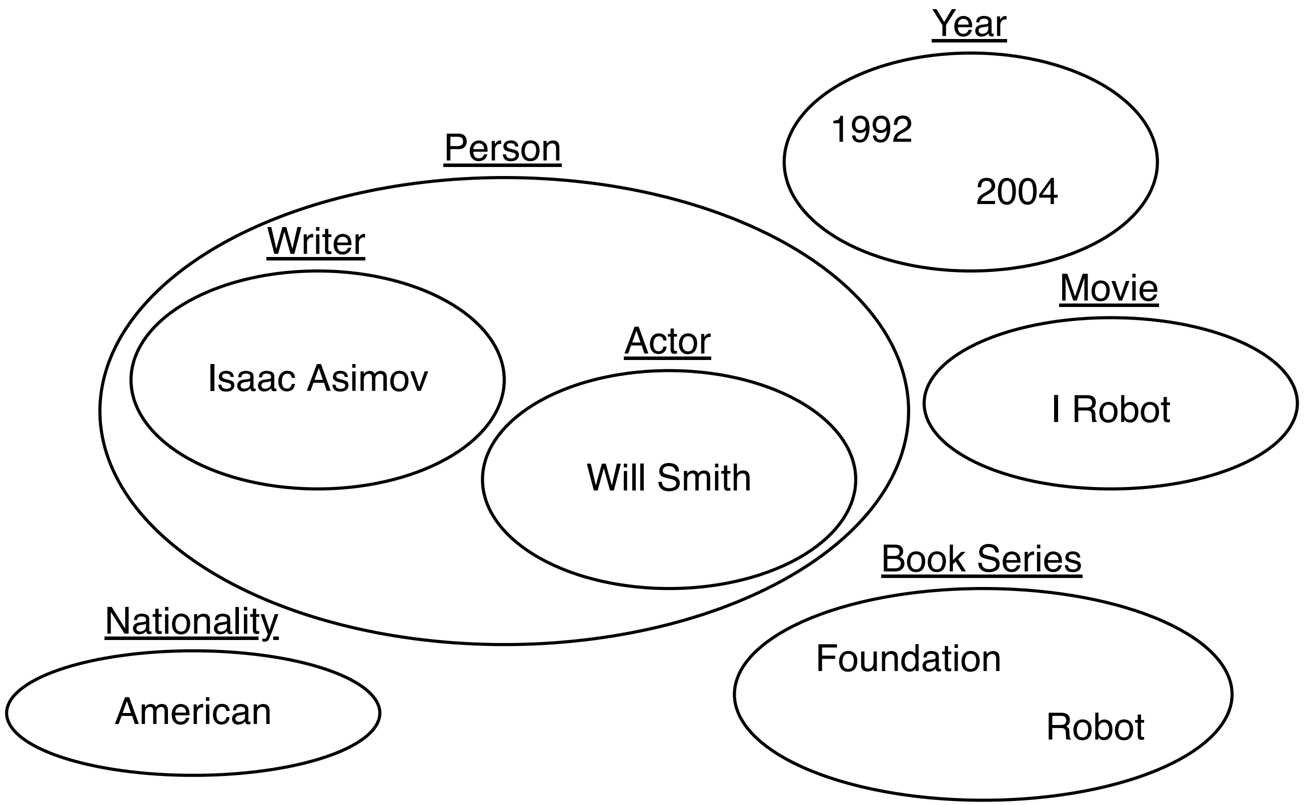
$$< Mona\ Lisa, Louvre > \in isExhibitedIn$$

$$< Leonardo\ da\ Vinci, Mona\ Lisa > \in hasPainted$$

$$< Bill, Mona\ Lisa > \in isInterestedIn$$

$$< Bill, Louvre > \in hasVisited$$

Exercize 15 – A LoE Model



$$< Isaac\ Asimov, Foundation > \in hasWrote$$

$$< Isaac\ Asimov, Robot > \in hasWrote$$

$$< I\ Robot, Robot > \in isAdaptationOf$$

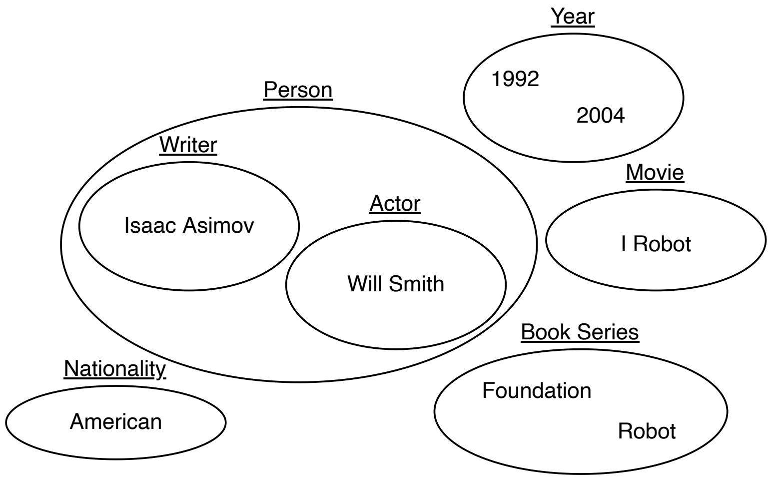
$$< I\ Robot, 2004 > \in producedIn$$

$$< Will\ Smith, I\ Robot > \in starredIn$$

$$< Isaac\ Asimov, 1992 > \in diedIn$$

$$< Isaac\ Asimov, American > \in hasNationality$$

Exercize 15 – From semantics to syntax



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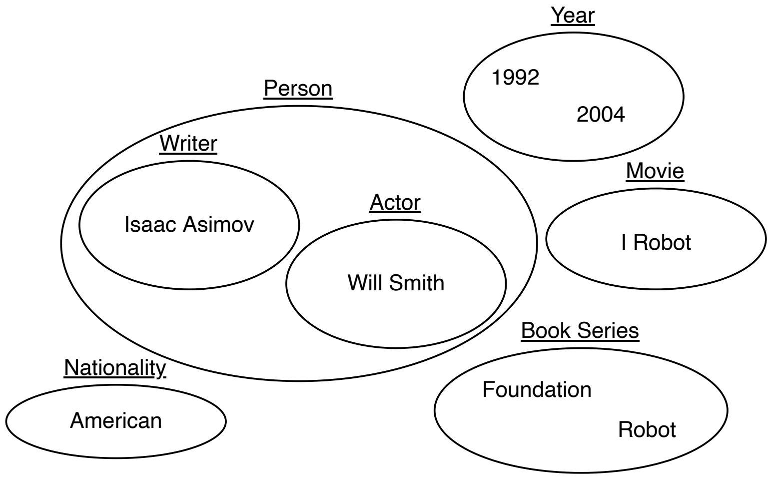
$$< Will\ Smith, I\ Robot > \in starredIn$$
$$< Isaac\ Asimov, 1992 > \in diedIn$$
$$< Isaac\ Asimov, American > \in hasNationality$$

$Writer(Isaac\ Asimov)$
$Actor(Will\ Smith)$
$Movie(I\ Robot)$
$BookSeries(Foundation)$
$BookSeries(Robot)$
$Nationality(American)$
$hasWrote(Isaac\ Asimov, Foundation)$
$hasWrote(Isaac\ Asimov, Robot)$
$isAdaptationOf(I\ Robot, Robot)$
$producedIn(I\ Robot, 2004)$
$starredIn(Will\ Smith, I\ Robot)$
$diedIn(Isaac\ Asimov, 1992)$
$hasNationality(Isaac\ Asimov, American)$

Exercize 15 – Define the interpretation function



$$< Isaac\ Asimov, Foundation > \in hasWrote$$

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$Writer(Isaac\ Asimov)$
$Actor(Will\ Smith)$
$Movie(I\ Robot)$
$BookSeries(Foundation)$
$BookSeries(Robot)$
$Nationality(American)$
$hasWrote(Isaac\ Asimov, Foundation)$
$hasWrote(Isaac\ Asimov, Robot)$
$isAdaptationOf(I\ Robot, Robot)$
$producedIn(I\ Robot, 2004)$
$starredIn(Will\ Smith, I\ Robot)$
$diedIn(Isaac\ Asimov, 1992)$
$hasNationality(Isaac\ Asimov, American)$

Exercize 16 – Define the interpretation function

Let there be a table, shown below, showing the grades, represented by an integer, of an exam (not explicitly stated). State for which of the domains D = <E, {C}, {R}> of the Logic of Entities below, there is an interpretation function that correctly formalizes the contents of the table. Assume that there are no synonyms.

Student	Domicile	Mark
MarioRossi	Trento	27
StefaniaBianchi	Napoli	30

- E = MarioRossi, StefaniaBianchi, Trento, Naples, twenty-seven, thirty
- {C} = Student, entity, integer, dtype
- {R} = Residence, Mark

Is false because in E the integers must be represented as integers (integer), where name and value must coincide; this is true for all data values.

Exercize 17 – Define the interpretation function

Let there be a table, shown below, showing the grades, represented by an integer, of an exam (not explicitly stated). State for which of the domains D = <E, {C}, {R}> of the Logic of Entities below, there is an interpretation function that correctly formalizes the contents of the table. Assume that there are no synonyms.

Student	Domicile	Mark
MarioRossi	Trento	27
StefaniaBianchi	Napoli	30

- E = MarioRossi, StefaniaBianchi, Trento, Naples, 27, 30
- {C} = Student, city, entity, integer, dtype
- {R} = Residence, Mark

Is true because it is okay to add in D more elements than the table (a model is a subset of the domain), i.e. in the specific case "city" as etype intended even if not explicitly represented in the table; note htat entity and dtype should always be put in C.

Exercize 18 – Define the interpretation function

Let there be a table, shown below, showing the grades, represented by an integer, of an exam (not explicitly stated). State for which of the domains D = <E, {C}, {R}> of the Logic of Entities below, there is an interpretation function that correctly formalizes the contents of the table. Assume that there are no synonyms.

Student	Domicile	Mark
MarioRossi	Trento	27
StefaniaBianchi	Napoli	30

- E = MarioRossi, StefaniaBianchi, Trento, Naples, 27, 30
- {C} = Student, entity, integer, dtype
- {R} = Residence, Mark

Is true because cities here are represented as elements of the entity set, that is, the set containing all entities.

Exercize 19 – Define the interpretation function

Let there be a table, shown below, showing the grades, represented by an integer, of an exam (not explicitly stated). State for which of the domains D = <E, {C}, {R}> of the Logic of Entities below, there is an interpretation function that correctly formalizes the contents of the table. Assume that there are no synonyms.

Student	Domicile	Mark
MarioRossi	Trento	27
StefaniaBianchi	Napoli	30

Is true because the domain can also have more elements than the table.

- E = MarioRossi, StefaniaBianchi, Trento, Naples, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
- {C} = Student, entity, integer, dtype
- {R} = Residence, Mark

Exercize 20 – Define the interpretation function

Let there be a table, shown below, showing the grades, represented by an integer, of an exam (not explicitly stated). State for which of the domains D = <E, {C}, {R}> of the Logic of Entities below, there is an interpretation function that correctly formalizes the contents of the table. Assume that there are no synonyms.

Student	Domicile	Mark
MarioRossi	Trento	27
StefaniaBianchi	Napoli	30

- E = MarioRossi, StefaniaBianchi, Trento, 27, 30
- {C} = Student,integer, entity, dtype
- {R} = Residence, Mark

Is false because an element for Naples is missing in E; a domain must have all the elements mentioned in the language, otherwise the corresponding interpretation cannot be defined.

Exercize 21 – Define the interpretation function

Let there be a table, shown below, showing the grades, represented by an integer, of an exam (not explicitly stated). State for which of the domains D = <E, {C}, {R}> of the Logic of Entities below, there is an interpretation function that correctly formalizes the contents of the table. Assume that there are no synonyms.

Student	**Domicile**	**Mark**
MarioRossi	Trento	27
StefaniaBianchi	Napoli	30

Is true because the interpretation function need not preserve names.

- E = MarioRossi, StefaniaBianchi, Bolzano, Rome, 27, 30
- {C} = Student,integer, entity, dtype
- {R} = Residence, Mark

Exercize 22 – Define the interpretation function

Let there be a table, shown below, showing the grades, represented by an integer, of an exam (not explicitly stated). State for which of the domains D = <E, {C}, {R}> of the Logic of Entities below, there is an interpretation function that correctly formalizes the contents of the table. Assume that there are no synonyms.

Student	Domicile	Mark
MarioRossi	Trento	27
StefaniaBianchi	Napoli	30

Is false because, given the table, residence cannot be an etype.

- E = MR, SB, TN, NA, 27, 30,
- {C} = Student, Residence, integer, entity, dtype
- {R} = Mark

Exercize 23 – Define the interpretation function

Let there be a table, shown below, showing the grades, represented by an integer, of an exam (not explicitly stated). State for which of the domains D = <E, {C}, {R}> of the Logic of Entities below, there is an interpretation function that correctly formalizes the contents of the table. Assume that there are no synonyms.

Student	Domicile	Mark
MarioRossi	Trento	27
StefaniaBianchi	Napoli	30

Is not a model definition because the formalization of the domain is not complete; the Rs are missing.

- E = MarioRossi, StefaniaBianchi, Trento, Naples, 27, 30,
- {C} = Student, integer, entity, dtype

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LoE Entailment

$Person(Alice)$
$Person(Bob)$
$Person(Bill)$
$City(Paris)$
$Monument(Eiffel\,Tower)$
$Museum(Louvre)$
$Painting(MonaLisa)$
$Painter(Leonardo\,da\,Vinci)$
$isFriendOf(Bob, Alice)$
$hasVisited(Alice, Eiffel\,Tower)$
$hasVisited(Bill, Eiffel\,Tower)$
$hasVisited(Bob, Louvre)$
$paintedBy(Mona\,Lisa, Leonardo\,da\,Vinci)$
$exhibitedIn(Mona\,Lisa, Louvre)$
$interestedIn(Bob, Mona\,Lisa)$
$isLocatedIn(Eiffel\,Tower, Paris)$
$isLocatedIn(Louvre, Paris)$

Given the model in LOE on the left, determine the truthness of the following statements using the close world assumption.

- $paintedBy(Mona\,Lisa, Leonardo\,da\,Vinci)$ True
- $hasVisited(Alice, Eiffel\,Tower)$ True
- $Person(Leonardo\,da\,Vinci)$ False

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Ask - Instance checking (same as LoE Entailment)

$Person(Alice)$
$Person(Bob)$
$Person(Bill)$
$City(Paris)$
$Monument(Eiffel\ Tower)$
$Museum(Louvre)$
$Painting(MonaLisa)$
$Painter(Leonardo\ da\ Vinci)$
$isFriendOf(Bob, Alice)$
$hasVisited(Alice, Eiffel\ Tower)$
$hasVisited(Bill, Eiffel\ Tower)$
$hasVisited(Bob, Louvre)$
$paintedBy(Mona\ Lisa, Leonardo\ da\ Vinci)$
$exhibitedIn(Mona\ Lisa, Louvre)$
$interestedIn(Bob, Mona\ Lisa)$
$isLocatedIn(Eiffel\ Tower, Paris)$
$isLocatedIn(Louvre, Paris)$

Given the model in LOE on the left, determine the truthness of the following statements using the open world assumption.

- The Louvre is in Paris — Yes
- Mona Lisa is exhibited at the Louvre — Yes
- Mona Lisa is in Paris — Don't know
- Bill and Alice visited the Eiffel Tower — Yes
- Bill and Alice visited the Eiffel Tower together — Don't know

Ask - Instance retrieval

$Person(Alice)$
$Person(Bob)$
$Person(Bill)$
$City(Paris)$
$Monument(Eiffel\ Tower)$
$Museum(Louvre)$
$Painting(MonaLisa)$
$Painter(Leonardo\ da\ Vinci)$
$isFriendOf(Bob, Alice)$
$hasVisited(Alice, Eiffel\ Tower)$
$hasVisited(Bill, Eiffel\ Tower)$
$hasVisited(Bob, Louvre)$
$paintedBy(Mona\ Lisa, Leonardo\ da\ Vinci)$
$exhibitedIn(Mona\ Lisa, Louvre)$
$interestedIn(Bob, Mona\ Lisa)$
$isLocatedIn(Eiffel\ Tower, Paris)$
$isLocatedIn(Louvre, Paris)$

• Who has visited the Eiffel Tower?	Alice, Bill
• Who is a friend of Bill?	N/A
• What can be found in Paris?	Louvre, Eiffel Tower
• Get all persons	Alice, Bob, Bill

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Key exercizes

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World models

the practice

(T2MP)