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Computational Logic Exercises

Module V – LOD applications and LODE

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Well formed formulas

Which of the following complex formulas are syntactically correct in LOD? (TBOX formulas)

- a) $A \equiv \exists R.C \sqcap \forall S.D$
- b) $A \sqcap B \equiv C \sqcup D$
- c) $A \equiv B \sqcap \neg C$
- d) $A \sqsubseteq \neg C$
- e) $A \sqsubseteq B \sqcap \exists R.C$
- f) $A \sqsubseteq B \sqcap \exists R.(\forall S.D)$
- g) $A \equiv B \sqcup \emptyset$

ANSWER:

a, c, d, e, f

Unfolding a Concept

Unfold ColouredGuitar:

ElectricGuitar \equiv Guitar \sqcap \forall hasSoundAmplification.withInputJack

ColouredGuitar \equiv ElectricGuitar \sqcap \exists hasColour.String

Answer:

ColouredGuitar \equiv Guitar \sqcap \forall hasSoundAmplification.withInputJack \sqcap \exists hasColour.String

Cyclic and acyclic TBOX

Is the following TBOX cyclic?

Woman \equiv Person \sqcap Female

Man \equiv Person \sqcap \neg Woman

Mother \equiv Woman \sqcap \exists hasChild.Person

Father \equiv Man \sqcap \exists hasChild.Person

Parent \equiv Father \sqcup Mother

ANSWER:

No, because by unfolding all concepts I never obtain the same concept on the left and on the right of the equivalences.

Cyclic and acyclic TBOX

Is the following TBOX cyclic?

Male $\equiv \neg$ Female

Female $\equiv \neg$ Male

ANSWER:

Yes, because by unfolding it I get Female $\equiv \neg(\neg$ Female) that is Female \equiv Female

Terminology

Is the following TBOX a terminology?

$\text{Mother} \equiv \text{Woman} \sqcap \exists \text{hasChild. Person}$

$\text{Father} \equiv \text{Man} \sqcap \exists \text{hasChild. Person}$

$\text{Parent} \equiv \text{Father} \sqcup \text{Mother}$

ANSWER:

Yes, because it is acyclic and there are only equivalences.

Terminology

Is the following TBOX a terminology?

Mother \equiv Woman $\sqcap \exists \text{hasChild. Person}$

Father \equiv Man $\sqcap \exists \text{hasChild. Person}$

Parent \sqsubseteq Father \sqcup Mother

ANSWER:

No, because it contains a subsumption.

Creating a terminology by expansion

Given the previous TBOX, provided below, can I convert it to make it a terminology?

Mother \equiv Woman \sqcap \exists hasChild.Person

Father \equiv Man \sqcap \exists hasChild.Person

Parent \sqsubseteq Father \sqcup Mother

ANSWER:

Yes, for instance as follows:

Mother \equiv Woman \sqcap \exists hasChild.Person

Father \equiv Man \sqcap \exists hasChild.Person

StepMother \equiv Woman \sqcap \exists marriedWith.Father

StepFather \equiv Man \sqcap \exists marriedWith.Mother

Parent \equiv Father \sqcup Mother \sqcup StepFather \sqcup StepMother

Defining a terminology from natural language definitions

A lion is a large gregarious predatory feline of Africa and India having a shaggy mane in the male

$\text{Lion} \equiv \text{Feline} \sqcap \text{Large} \sqcap \text{Gregarious} \sqcap \text{Predatory} \sqcap \forall \text{livesIn.}(\text{Africa} \sqcup \text{India}) \sqcap \exists \text{livesIn.}(\text{Africa} \sqcup \text{India})$

$\text{MaleLion} \equiv \text{Lion} \sqcap \text{Male} \sqcap \forall \text{has.ShaggyMane} \sqcap \exists \text{has.ShaggyMane}$

A penguin is a flightless bird of Antarctica having webbed feet

$\text{Penguin} \equiv \text{Bird} \sqcap \neg \text{Fly} \sqcap \forall \text{livesIn.Antarctica} \sqcap \exists \text{livesIn.Antarctica} \sqcap \forall \text{has.WebbedFeet} \sqcap \exists \text{has.WebbedFeet}$

Defining a terminology from a schema

[Thing](#) > [Event](#)

Property	Expected Type
Properties from Event	
about	Thing
actor	Person
attendee	Organization or Person

ANSWER. By assuming the schema as complete (otherwise it is not a terminology) we have:

$\text{Event} \equiv \text{Thing} \sqcap$

$\forall \text{about. Thing} \sqcap \exists \text{about. Thing} \sqcap$

$\forall \text{actor. Person} \sqcap \exists \text{actor. Person} \sqcap$

$\forall \text{attendee. (Person} \sqcup \text{Organization)} \sqcap \exists \text{attendee. (Person} \sqcup \text{Organization)}$

Logical consequences of a terminology (by unfolding)

Given the previous TBOX, replicated on the right, which of the following are logical consequences of the TBOX?

- a) $\text{Event} \sqsubseteq \forall \text{about.Thing} \sqcap \exists \text{about.Thing}$
- b) $\text{Event} \sqsubseteq \forall \text{about.Thing}$
- c) $\text{Event} \sqsubseteq \exists \text{about.Thing}$
- d) $\text{Event} \equiv \forall \text{about.Thing} \sqcap \exists \text{about.Thing}$
- e) $\text{Event} \sqsubseteq \forall \text{attendee.Person} \sqcup \forall \text{attendee.Organization}$
- f) $\text{Event} \sqsubseteq \forall \text{attendee.Person}$
- g) $\text{Person} \sqsubseteq \neg \text{Organization}$

ANSWER.

a, b, c, f

TBOX

$\text{Event} \equiv \text{Thing}$

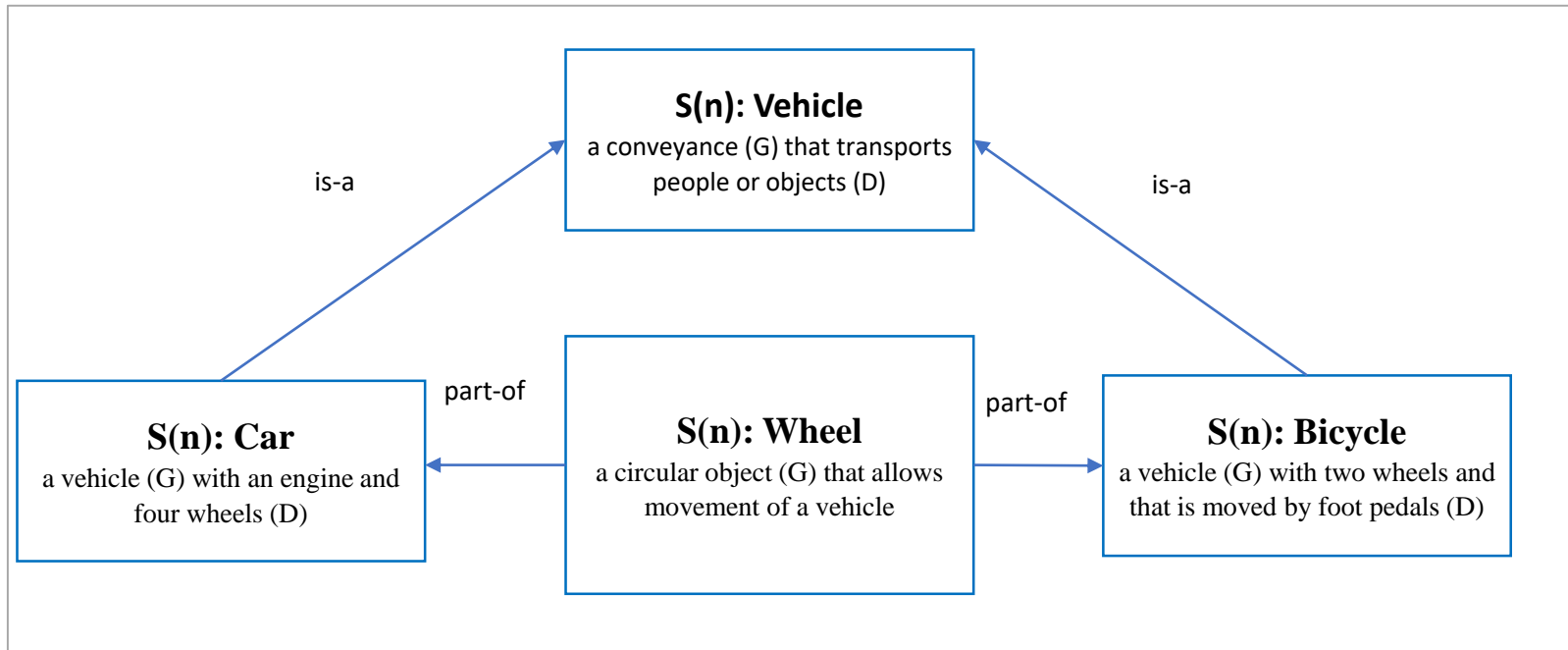
$\sqcap \forall \text{about.Thing} \sqcap \exists \text{about.Thing}$

$\sqcap \forall \text{actor.Person} \sqcap \exists \text{actor.Person} \sqcap$

$\forall \text{attendee.}(\text{Person} \sqcup \text{Organization}) \sqcap$

$\exists \text{attendee.}(\text{Person} \sqcup \text{Organization})$

Formalizing a lexicon as a terminology (I)



Vehicle \equiv Conveyance $\sqcap \exists \text{ transports.}(\text{Person} \sqcup \text{Object}) \sqcap \forall \text{ transports.}(\text{Person} \sqcup \text{Object})$

Car \equiv Vehicle $\sqcap \neg \text{Bicycle} \sqcap \exists \text{ hasPart.Wheel} \sqcap \exists \text{ hasPart.Engine}$

Bicycle \equiv Vehicle $\sqcap \exists \text{ hasPart.Wheel} \sqcap \exists \text{ hasPart.FootPedal} \sqcap \exists \text{ movedBy.FootPedal} \sqcap \forall \text{ movedBy.FootPedal}$

Wheel \equiv Object $\sqcap \text{CircularShape} \sqcap \exists \text{ moves.Vehicle} \sqcap \forall \text{ moves.Vehicle}$

Reasoning in LOD

Suppose we model the Monkey-Banana problem as follows:

“If the monkey is low in position then it cannot get the banana. If the monkey gets the banana it survives”.

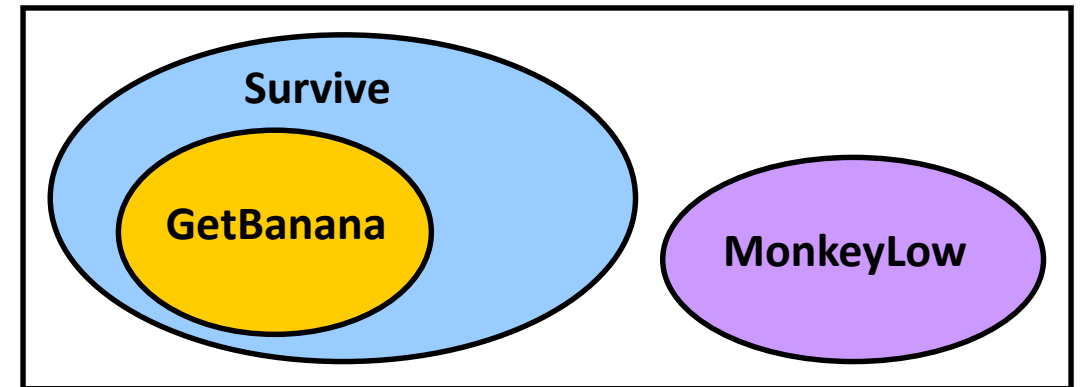
Theory T:

$\text{MonkeyLow} \sqsubseteq \neg \text{GetBanana}$

$\text{GetBanana} \sqsubseteq \text{Survive}$

Is T satisfiable?

ANSWER: Yes. It is enough to find one model for it, represented graphically with the Venn Diagram below.



Reasoning in LOD

Suppose we model the Monkey-Banana problem as follows:

“If the monkey is low in position then it cannot get the banana. If the monkey gets the banana it survives”.

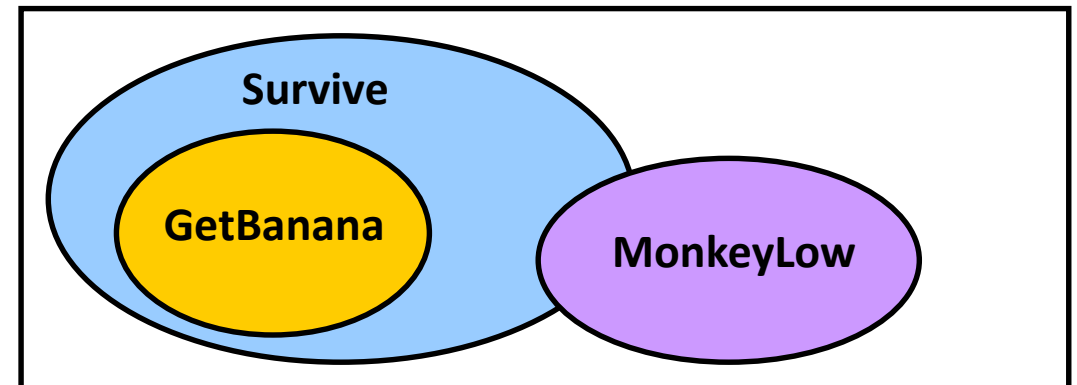
Theory T:

$\text{MonkeyLow} \sqsubseteq \neg \text{GetBanana}$

$\text{GetBanana} \sqsubseteq \text{Survive}$

Is it possible for a monkey to survive even if it does not get the banana?

ANSWER: We can restate the problem as follow:
does $T \models \neg \text{GetBanana} \sqcap \text{Survive}$ at least in one model?
Yes. We can find a model in which both all the assertions in T and $\neg \text{GetBanana} \sqcap \text{Survive}$ are not empty.



Reasoning in LOD

Suppose we describe students in a course as follows:

Undergraduate	$\sqsubseteq \neg \text{Teach}$
Bachelor	$\equiv \text{Student} \sqcap \text{Undergraduate}$
Master	$\equiv \text{Student} \sqcap \neg \text{Undergraduate}$
PhD	$\equiv \text{Master} \sqcap \text{Research}$
Assistant	$\equiv \text{PhD} \sqcap \text{Teach}$

Are all assistants also undergraduates?

ANSWER: We can restate the problem as follow:
does $T \models \text{Assistant} \sqsubseteq \text{Undergraduate}$?

We need to prove that this is true in all models (via the method of *unfolding*)

$\text{Assistant} \equiv \text{PhD} \sqcap \text{Teach}$
 $\equiv \text{Master} \sqcap \text{Research} \sqcap \text{Teach}$
 $\equiv \text{Student} \sqcap \neg \text{Undergraduate} \sqcap$
 $\text{Research} \sqcap \text{Teach}$

Answer is No. Assistants are actually students who are not undergraduate.

Reasoning in LOD

Suppose we model the Monkey-Banana problem as follows:

“If the monkey is low in position then it cannot get the banana. If the monkey gets the banana it survives”.

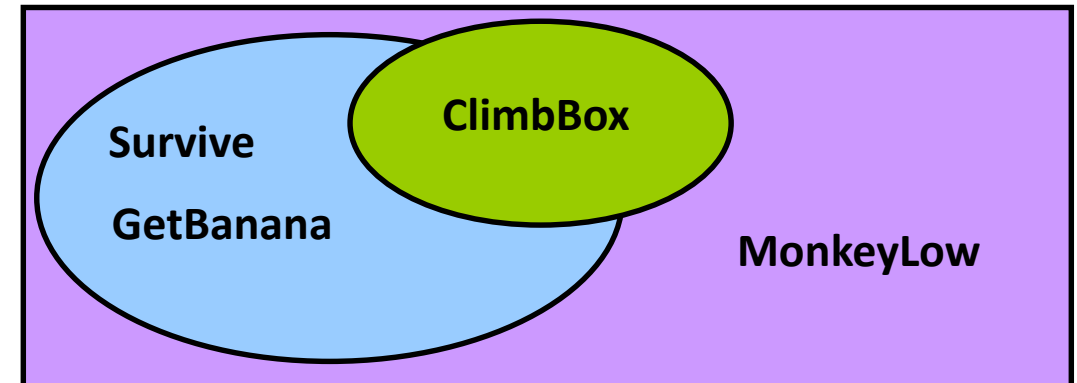
Theory T:

$\text{MonkeyLow} \equiv \neg \text{GetBanana} \sqcap \neg \text{ClimbBox}$

$\text{GetBanana} \equiv \text{Survive}$

Is it possible for a monkey to climb the box and not survive?

ANSWER: We can restate the problem as follow:
does $T \models \text{ClimbBox} \sqcap \neg \text{Survive}$ at least in one model?
Yes. We can find a model in which both all the assertions in T and $\text{ClimbBox} \sqcap \neg \text{Survive}$ are not empty.



Reasoning in LOD

Suppose we describe students in a course as follows:

Undergraduate	$\sqsubseteq \neg \text{Teach}$
Bachelor	$\equiv \text{Student} \sqcap \text{Undergraduate}$
Master	$\equiv \text{Student} \sqcap \neg \text{Undergraduate}$
PhD	$\equiv \text{Master} \sqcap \text{Research}$
Assistant	$\equiv \text{PhD} \sqcap \text{Teach}$

Are bachelor and master disjoint?

ANSWER: We can restate the problem as follow:

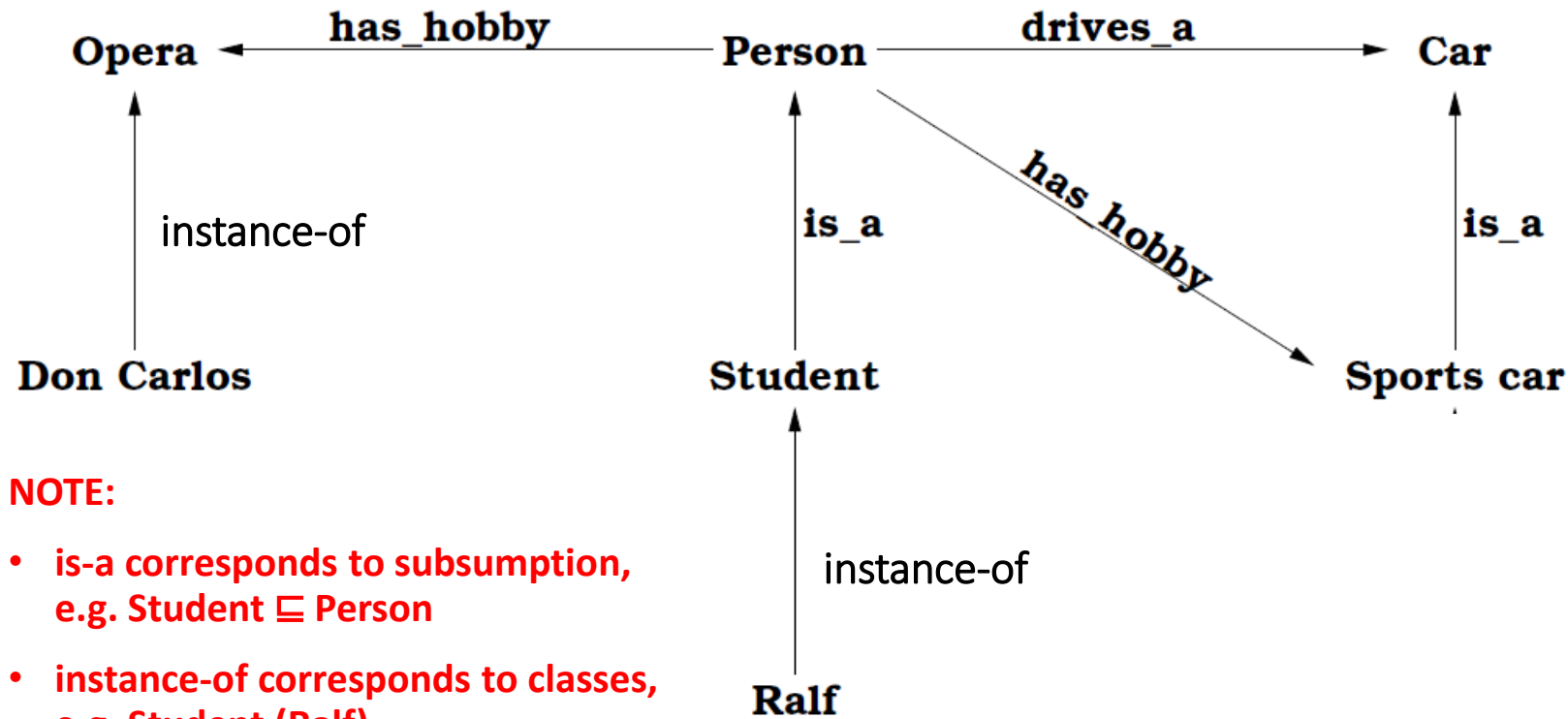
does $T \models \text{Bachelor} \sqcap \text{Master} \sqsubseteq \perp$?

We need to prove that this is true in all models (via the method of *unfolding*)

Answer is obviously Yes because they contain two opposite constraints.

Define a LODE theory

Define a LODE theory for the following knowledge graph



ANSWER:

$$\begin{aligned} \text{Person} \sqsubseteq & \exists \text{Drives.Car} \sqcap \\ & \exists \text{HasHobby.SportCar} \sqcap \\ & \exists \text{HasHobby.Opera} \end{aligned}$$

$$\text{Student} \sqsubseteq \text{Person}$$

$$\text{SportCar} \sqsubseteq \text{Car}$$

$$\text{Student}(\text{Ralf})$$

$$\text{Opera}(\text{DonCarlos})$$

Define a LODE theory

Define a LODE theory for the following problem:

In a hospital patients, doctors and computers are equipped with proximity sensors able to detect whether doctors curated a patient or worked at their computer. The system detected that doctor Peter curated the patient Smith.

ANSWER:

Doctor $\sqsubseteq \forall \text{cure.Patient} \sqcap \forall \text{work.Computer}$

cure $\sqsubseteq \text{detected}$

work $\sqsubseteq \text{detected}$

Doctor (Peter)

Patient (Smith)

cure(Peter, Smith)

Expansion of a LODE concept

Given the following TBOX, compute the expansion of the ABox $A = \{\text{StepMother}(\text{Mary})\}$

$\text{Mother} \equiv \text{Woman} \sqcap \exists \text{hasChild}.\text{Person}$

$\text{Father} \equiv \text{Man} \sqcap \exists \text{hasChild}.\text{Person}$

$\text{StepMother} \equiv \text{Woman} \sqcap \exists \text{marriedWith}.\text{Father}$

$\text{StepFather} \equiv \text{Man} \sqcap \exists \text{marriedWith}.\text{Mother}$

$\text{Parent} \equiv \text{Father} \sqcup \text{Mother} \sqcup \text{StepFather} \sqcup \text{StepMother}$

ANSWER:

$\text{StepMother}(\text{Mary}), \text{Woman}(\text{Mary}), \text{marriedWith}(\text{Mary}, a1), \text{Father}(a1)$

Expansion of a LODE concept

Given the following TBOX, compute the expansion of the ABox $A = \{\text{StepMother}(\text{Mary}), \text{marriedWith}(\text{Mary}, \text{Paul})\}$

$\text{Mother} \equiv \text{Woman} \sqcap \exists \text{hasChild}.\text{Person}$

$\text{Father} \equiv \text{Man} \sqcap \exists \text{hasChild}.\text{Person}$

$\text{StepMother} \equiv \text{Woman} \sqcap \neg \text{marriedWith}.\text{Father}$

$\text{StepFather} \equiv \text{Man} \sqcap \exists \text{marriedWith}.\text{Mother}$

$\text{Parent} \equiv \text{Father} \sqcup \text{Mother} \sqcup \text{StepFather} \sqcup \text{StepMother}$

ANSWER:

$\text{StepMother}(\text{Mary}), \text{Woman}(\text{Mary}), \text{marriedWith}(\text{Mary}, \text{Paul}), \text{Father}(\text{Paul})$

Instance checking in LODE

Given the following LODE theory T, does $T \models \text{Professor}(\text{John})$?

$\text{Lecturer} \equiv \forall \text{Teaches.Course} \sqcap \neg \text{Undergrad} \sqcap \text{Professor}$

$\text{Lecturer}(\text{John})$

$\text{Teaches}(\text{John}, \text{Logics})$

$\text{Course}(\text{Logics})$

ANSWER:

The expansion of $\text{Lecturer}(\text{John})$ is $\{\text{Teaches}(\text{John}, \text{Logics}), \text{Course}(\text{Logics}), \neg \text{Undergrad}(\text{John}), \text{Professor}(\text{John})\}$

Therefore the answer is **yes**.

Instance retrieval in LODE

Given the following LODE theory T, find all the instances of Lecturer.

$\text{Lecturer} \equiv \forall \text{Teaches.Course} \sqcap \neg \text{Undergrad} \sqcap \text{Professor}$

$\text{Lecturer}(\text{John})$

$\text{Teaches}(\text{John}, \text{Logics})$

$\text{Course}(\text{Logics})$

$\text{Teaches}(\text{Paul}, \text{Logics})$

$\neg \text{Undergrad}(\text{Paul})$

$\text{Professor}(\text{Paul})$

ANSWER:

$\{\text{John}, \text{Paul}\}$

In fact, John is in the ABox, while Paul satisfies all the constraints in the definition of Lecturer.

Concept realization in LODE

Given the following LODE theory T, find the most specific concept for Paul.

$\text{Lecturer} \equiv \forall \text{Teaches.Course} \sqcap \neg \text{Undergrad} \sqcap \text{Professor}$

$\text{Lecturer}(\text{John})$

$\text{Teaches}(\text{John}, \text{Logics})$

$\text{Course}(\text{Logics})$

$\text{Teaches}(\text{Paul}, \text{Logics})$

$\neg \text{Undergrad}(\text{Paul})$

$\text{Professor}(\text{Paul})$

ANSWER:

Given that Paul satisfies all the constraints in the definition of Lecturer, the answer is Lecturer.

Note that if we remove $\text{Professor}(\text{Paul})$, the answer becomes $\{\neg \text{Undergrad}\}$