Semantic Web – Tutorial #2

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1: Modelling Ontologies via $\mathcal{ALC}$

1: Modelling Ontologies via $\mathcal{ALC}$ | Task

Consider the following domain specification of a company which sells some products:

From a company point of view, a person is either a staff member or a customer. The company staff consists of salespersons and bosses. Each salesperson works for a boss. Bosses don't work for anyone. A customer is served by at least one staff member. Although a customer can be served by any staff member, only salespersons can sell products. A salesperson sells at least one product.

You are also given the following pieces of information: Anna is the boss of the two salespeople Barbara and Carl. David is a customer served by Barbara. Edna sells a car.

In this task, you shall formalize the company specification domain above in $\mathcal{ALC}$. Follow the guidelines below to perform this task.

Domain Specification

From a company point of view, a *person* is either a *staff member* or a *customer*. The company *staff* consists of *salespersons* and *bosses*. Each *salesperson* **works for** a *boss*. *Bosses* **don't work** for anyone. A *customer* is **served by** at least one *staff member*. Although a *customer* can be **served by** any *staff member*, only *salespersons* can **sell** *products*. A *salesperson* **sells** at least one *product*.

You are also given the following pieces of information: Anna is the *boss* of the two *salespeople* Barbara and Carl. David is a *customer* **served by** Barbara. Edna **sells** a car.

Task: Define a set N_C of concepts, a set N_R of roles, and a set N_O of individual names for the company domain above.

$$N_C = \{\text{Person}, \text{StaffMember}, \text{Salesperson}, \text{Boss}, \text{Customer}, \text{Product}\}$$

$$N_R = \{\text{worksFor}, \text{servedBy}, \text{sells}\}$$

$$N_O = \{\text{Anna}, \text{Barbara}, \text{Carl}, \text{David}, \text{Edna}, \text{Car}\}$$

1: Modelling Ontologies via $\mathcal{ALC}$

Task: Using the sets N_C and N_R you defined on the previous step, and only those, define a *TBox* in $\mathcal{ALC}$ for the company domain. Your specification must contemplate all information provided above.

Concepts, Roles, Individual Names

- $N_C = \{\text{Person}, \text{StaffMember}, \text{Salesperson}, \text{Boss}, \text{Customer}, \text{Product}\}$
- $N_R = \{\text{worksFor}, \text{servedBy}, \text{sells}\}$
- $N_O = \{\text{Anna}, \text{Barbara}, \text{Carl}, \text{David}, \text{Edna}, \text{Car}\}$

$$
\begin{aligned}
\mathcal{T} = \{&\text{StaffMember} \sqcup \text{Customer} \equiv \text{Person},\\
&\text{Salesperson} \sqcup \text{Boss} \equiv \text{StaffMember},\\
&\text{Salesperson} \sqsubseteq \exists \text{worksFor}.\text{Boss},\\
&\text{Boss} \sqsubseteq \neg\exists \text{worksFor}.\top,\\
&\text{Customer} \sqsubseteq \exists \text{servedBy}.\text{Staffmember},\\
&\text{Salesperson} \sqsubseteq \exists \text{sells}.\text{Product},\\
&\exists \text{sells}.\text{Product} \sqsubseteq \text{Salesperson}\}
\end{aligned}
$$

Task: Using N_C, N_R and N_O, define an *ABox* in $\mathcal{ALC}$ to the company scenario above.

$$\begin{aligned}\mathcal{A} = \{&\text{Anna} : \text{Boss},\\ &\text{Barbara} : \text{Salesperson},\\ &\text{Carl} : \text{Salesperson},\\ &\text{David} : \text{Customer},\\ &(\text{Barbara}, \text{Anna}) : \text{worksfor},\\ &(\text{Carl}, \text{Anna}) : \text{worksfor},\\ &(\text{David}, \text{Barbara}) : \text{servedBy},\\ &(\text{Edna}, \text{Car}) : \text{sells}\}\end{aligned}$$

2: Interpretations in $\mathcal{ALC}$

Consider the following list of statements that describe a hospital:

1. A *Staff Member* is either a *Nurse*, a *Physician* or a *Janitor*.
2. The concepts *Nurse*, *Physician* and *Janitor* are pairwise disjoint.
3. A *Patient* is a *Person* who *gets treated* for at least one *Illness*.
4. A *Nurse* is a *Person* who *takes care of* at least one *Patient*.
5. A *Janitor* cannot *take care of* any *Patients*.
6. Only *Physicians* can treat *Illnesses*.

The following *TBox* $\mathcal{T}_1$ is an attempt to formalize the statements (4) - (6) in $\mathcal{ALC}$:

$$
\begin{array}{lllll}
\mathcal{T}_1 = \{ & \text{Nurse} & \sqsubseteq & \forall \text{takesCareOf.Patient} & \\
 & \neg\exists \text{takesCareOf.Patient} & \sqsubseteq & \text{Janitor} & \\
 & \forall \text{canTreat.Illness} & \sqsubseteq & \text{Physician} & \}
\end{array}
$$

Task: Does $\mathcal{T}_1$ capture the statements (4)–(6) above? If yes, define a model for $\mathcal{T}_1$; otherwise:

- show 2 rules from $\mathcal{T}_1$ that violates some of the statements (4) - (6), and indicate which statements each of the rules you identified violates;
- for each rule you pointed out, give a brief explanation of why it violates the respective statement; and
- provide a model for $\mathcal{T}_1$ that fails such statements.

You must briefly explain why your model satisfies or does not satisfy $\mathcal{T}_1$.

No, $\mathcal{T}_1$ does *not* capture statements (4)–(6).

- Nurse $\sqsubseteq \forall$takesCareOf.Patient violates (4) [*A Nurse is a Person who takes care of at least one Patient*]:
  - It says that nurses only take care of patients, whereas (4) says that a nurse takes care of *at least one* patient.
  - The $\forall$ allows a nurse to take care of zero patients.
- $\neg\exists$takesCareOf.Patient $\sqsubseteq$ Janitor violates (5) [*A Janitor cannot take care of any Patients*]:
  - It says that anyone who does not take care of a patient is a janitor. (5), however, says the opposite: if someone is a janitor, they do not take care of any patient.
- $\forall$canTreat.Illness $\sqsubseteq$ Physician violates (6) [*Only Physicians can treat Illnesses*]:
  - It says that all those who can treat only illnesses are physicians, but (6) says the opposite: only physicians can treat illnesses.

Consider the interpretation $I = (\Delta^I, \cdot^I)$, where

$$\begin{aligned}
\Delta^I &= \{n_1, n_2, p_1, j_1, i_1\} \\
\mathsf{Nurse}^I &= \{n_1, n_2\} \\
\mathsf{Patient}^I &= \{p_1\} \\
\mathsf{Janitor}^I &= \{j_1\} \\
\mathsf{Illness}^I &= \{i_1\} \\
\mathsf{Physician}^I &= \{n_1, n_2, p_1, i_1\} \\
\mathsf{takesCareOf}^I &= \{(n_1, p_1), (j_1, p_1)\} \\
\mathsf{canTreat}^I &= \{(j_1, i_1), (j_1, p_1)\}
\end{aligned}$$

I satisfies $\mathcal{T}_1$ but does not satisfy neither of the statements (4)–(6). Both nurses n_1 and n_2 only take care of patients (n_2 satisfies it vacuously, since it takes care of no patient), but it violates (4) since n_2 takes care of no patient. Moreover, (5) is violated, because j_1, a janitor, takes care of the patient p_1. Statement (6) is violated, because j_1 treats the illness i_1.

2: Interpretations in $\mathcal{ALC}$

Task: Formalize each of the statements above in $\mathcal{ALC}$.

1. A *Staff Member* is either a *Nurse*, a *Physician* or a *Janitor*.
   - $\mathsf{StaffMember} \sqsubseteq \mathsf{Nurse} \sqcup \mathsf{Physician} \sqcup \mathsf{Janitor}$
2. The concepts *Nurse*, *Physician* and *Janitor* are pairwise disjoint.
   - $(\mathsf{Nurse} \sqcap (\mathsf{Physician} \sqcup \mathsf{Janitor})) \sqcup (\mathsf{Physician} \sqcap \mathsf{Janitor}) \sqsubseteq \bot$
3. A *Patient* is a *Person* who *gets treated* for at least one *Illness*.
   - $\mathsf{Patient} \sqsubseteq \mathsf{Person} \sqcap \exists \mathsf{getsTreatedFor}.\mathsf{Illness}$
4. A *Nurse* is a *Person* who *takes care of* at least one *Patient*.
   - $\mathsf{Nurse} \sqsubseteq \mathsf{Person} \sqcap \exists \mathsf{takesCareOf}.\mathsf{Patient}$
5. A *Janitor* cannot *take care of* any *Patients*.
   - $\exists \mathsf{takesCareOf}.\mathsf{Patient} \sqcap \mathsf{Janitor} \sqsubseteq \bot$
6. Only *Physicians* can treat *Illnesses*.
   - $\exists \mathsf{canTreat}.\mathsf{Illness} \sqsubseteq \mathsf{Physician}$

2: Interpretations in $\mathcal{ALC}$

Task: Define a model for the *TBox* you defined in the previous step. Your interpretation must have at least one instance for each concept, and each relation must have at least one pair.

$I = (\Delta^I, \cdot^I)$, with $\Delta^I = \{n_1, j_1, q_1, p_1, i_1\}$

$$
\begin{aligned}
\text{Person}^I &= \{n_1, j_1, q_1, p_1\} \\
\text{StaffMember}^I &= \{n_1, j_1, q_1\} \\
\text{Nurse}^I &= \{n_1\} \\
\text{Janitor}^I &= \{j_1\} \\
\text{Physician}^I &= \{q_1\} \\
\text{Patient}^I &= \{p_1\} \\
\text{Illness}^I &= \{i_1\} \\
\text{getsTreatedFor}^I &= \{(p_1, i_1)\} \\
\text{takesCareOf}^I &= \{(n_1, p_1)\} \\
\text{canTreat}^I &= \{(q_1, i_1)\}
\end{aligned}
$$