Chapter 6

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Modeling with Description Logic

- Discusses the added value brought about by “certain DL modeling features”
- Syntactic sugar
  - “Features expressible with stuff you already have”
- Provide insight about model-theoretic consequences that arise from using or not using certain constructs
- … basically a bunch of recipes for basic logical constructs

A lot can be done in ALC

- ALC - *Attributive Concept Language with Complements*
  - “The prototypical DL”
- Features of ALC
Atomic concepts	A, B
Not	$\neg C$
And	$C \cap D$
Or	$C \cup D$
Exists	$\exists r. C$
For all	$\forall r. C$

Concept Disjointness

- “Two concepts C and D are disjoint with respect to an interpretation I, if their extensions do not overlap”
  - Basically means: They have nothing in common
- Formal definitions
  - $C^{\mathcal{I}} \cap D^{\mathcal{I}} = \emptyset$

    $C \cap D \sqsubseteq \bot$

    $C \sqsubseteq \neg D$

General Concept Inclusion

- Use case → Guarantee that some individual is *not* an instance of a concept

Domain and Range of Roles

- Given a **role**, we want **statements** about the **source** and **target** for the respective relation
- Domain
  - Role, **r** has *domain* **C** in an interpretation **I**, if any *source* individual of the relation associated with **r**, is an instance of **C**
  - Definition: $\exists r.\top \sqsubseteq C \longrightarrow \exists \text{authorOf}.\top \sqsubseteq \text{Person}$
- Range
  - No intuitive explanation
  - Definition $\top \sqsubseteq \forall r.D \longrightarrow \top \sqsubseteq \forall \text{authorOf}.\text{Publication}$

source

$$\langle \delta, \delta' \rangle \in r^{\mathcal{I}}$$

target

The Empty Role and Inverses

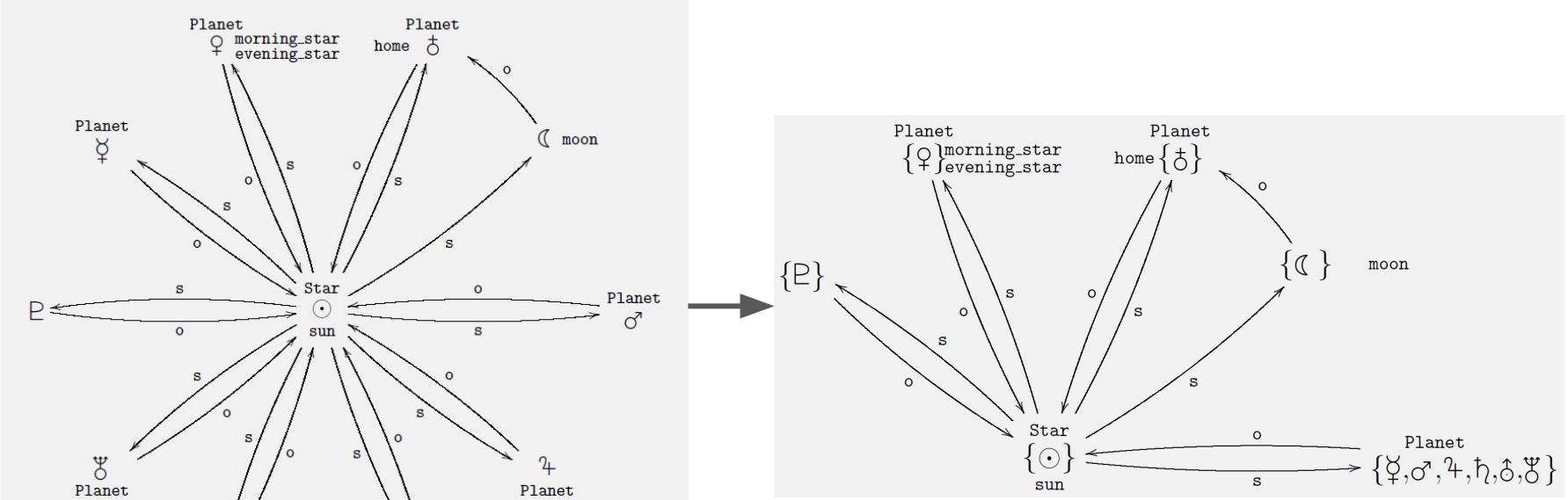
- The empty role
  - SROIQ has universal and empty concept definitions ($\top$ and $\bot$), but only universal role, u
  - Empty role missing!
  - New definition: $\top \sqsubseteq \forall \mathtt{emptyRole}.\bot$
- Inverses
  - Inverses allow for traversing roles in reverse direction
    - Can describe individuals with “incoming” roles, as well as “outgoing”
  - Use case → Symmetricity
    - $\mathtt{r}^- \sqsubseteq \mathtt{r} \longrightarrow \mathtt{marriedWith}^- \sqsubseteq \mathtt{marriedWith}$

Model Manipulation Part I - Filtration

- *“Given a set C of concepts, and an interpretation I, we can obtain the filtration of I with respect to C, by creating an equivalence relation* $\simeq$ *and letting* $\delta \simeq \delta'$ *if they coincide in terms of concept memberships”*

- Basically a super complicated way of saying “grouping by concept”

Model Manipulation Part I - Filtration



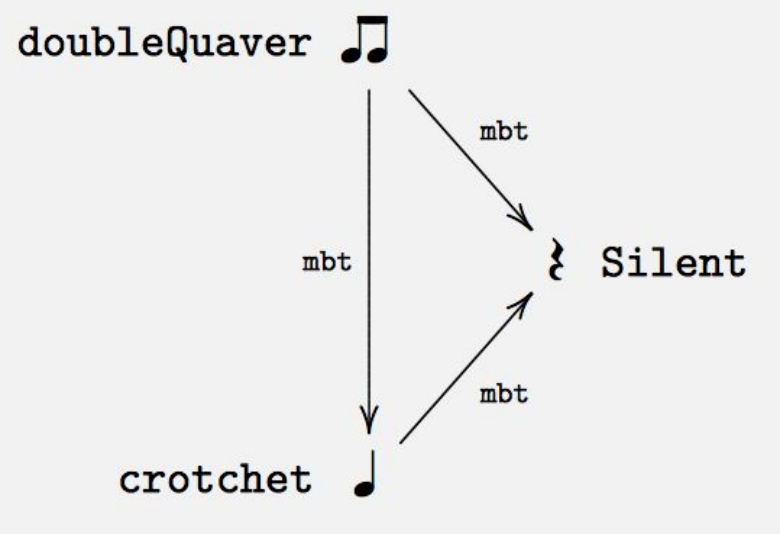
Up to Infinity: Cardinality Constraints

- *“Create statements about the number of individuals related to a certain individual via a role”*
- Should be known from UML and DB-modeling
- 1 to 1, 1 to many, many to many-relationships on roles
- “Value” can also be arbitrary or exact
- Ex: $\texttt{Polygamist} \sqsubseteq \geqslant 2.\texttt{Married}.\top$
- Functional roles
  - Roles with at most 1 individual in the **target** end
  - i.e. hasFather

Model Manipulation Part II: Unraveling

- Unfold a model such that all the parts of the model not containing named individuals are tree-like.

Example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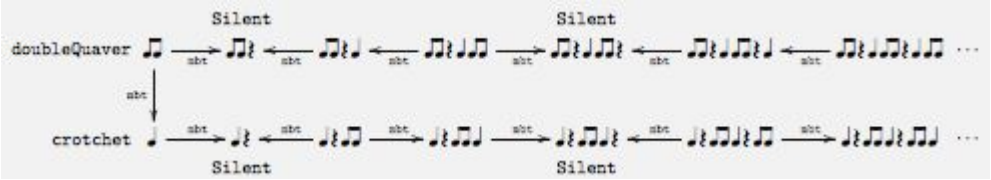
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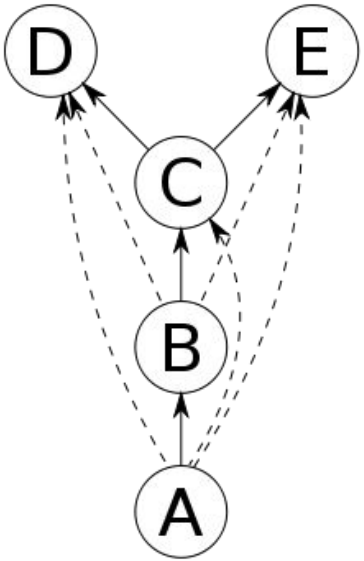
Far far away: Transitivity

- Examples : ancestorOf, superiorOf, partOf, greaterThan
- Can’t precisely talk about the transitive closure of a given role



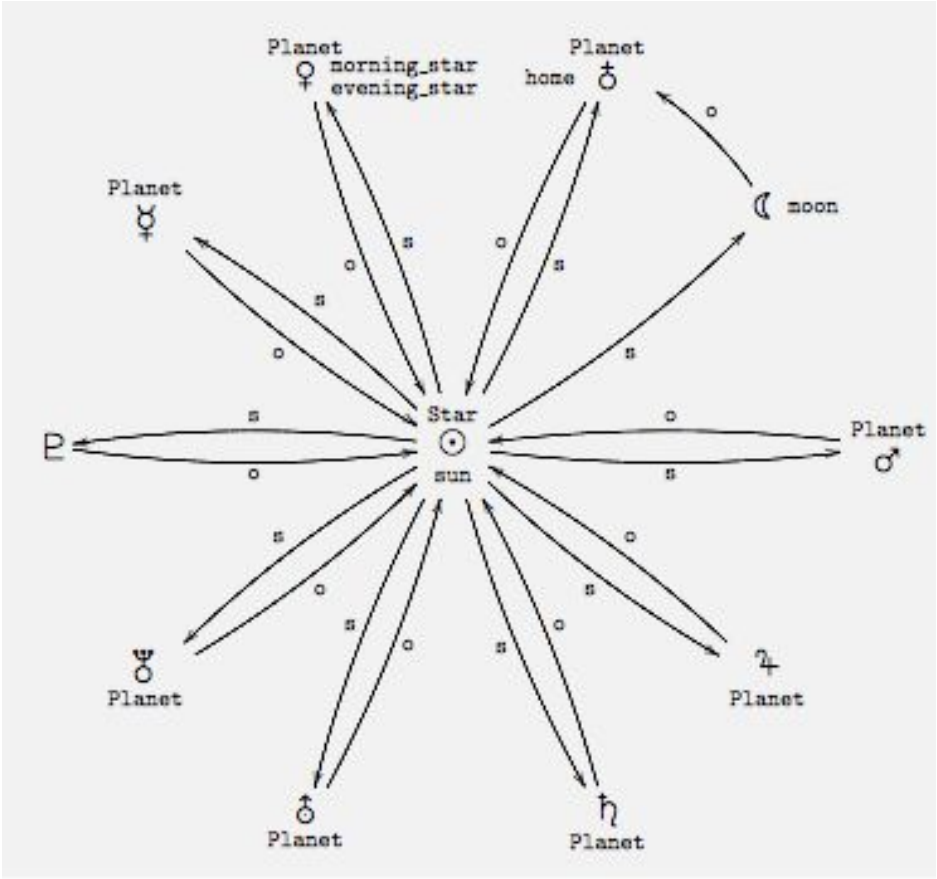
Model Manipulation Part III: Disjoint Union

$$\mathcal{I} = (\Delta^{\mathcal{I}}, \cdot^{\mathcal{I}}) \text{ and } \mathcal{J} = (\Delta^{\mathcal{J}}, \cdot^{\mathcal{J}})$$

$$\Delta^{\mathcal{I}+\mathcal{J}} = \Delta^{\mathcal{I}} \cup \Delta^{\mathcal{J}}. \; \mathtt{a}^{\mathcal{I}+\mathcal{J}} = \mathtt{a}^{\mathcal{I}}. \; \mathtt{A}^{\mathcal{I}+\mathcal{J}} = \mathtt{A}^{\mathcal{I}} \cup \mathtt{A}^{\mathcal{J}}$$

$$\mathbf{r}^{\mathcal{I}+\mathcal{J}} = \mathbf{r}^{\mathcal{I}} \cup \mathbf{r}^{\mathcal{J}}$$

Example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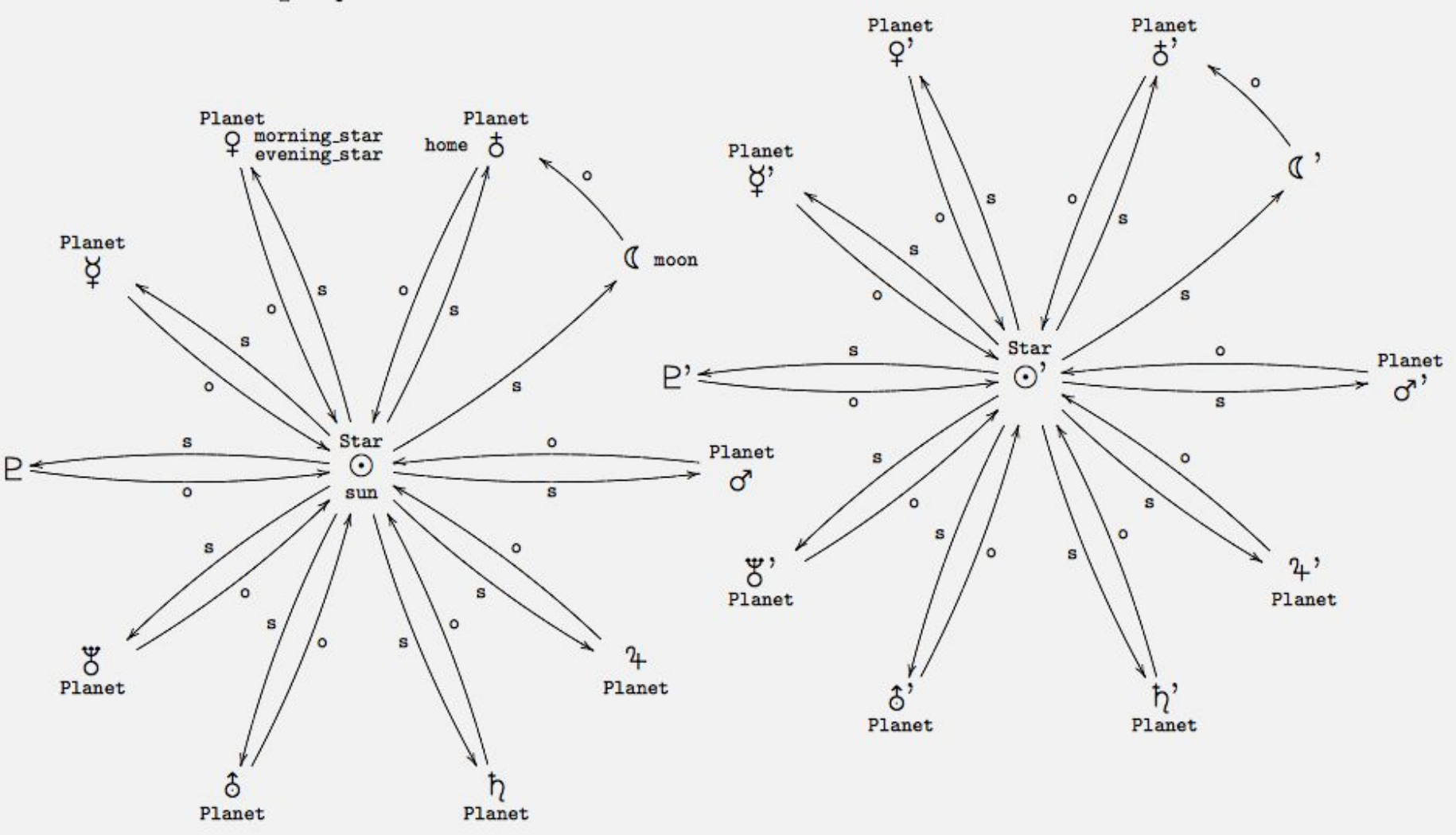
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Know your Bounds: Nominal Concept and Universal Role

- The modeling power brought about by nominal concepts and universal roles is quite similar
- Capability to bound or fix the number of individuals in the extension of a class or even in the whole domain.

Selfishness

- The self concept enables to speak about “role loops”
- Allows to define concepts based on such situations

Closed/Open World Assumption

- In the *Closed World Assumption* everything in the knowledge base is **true**, everything else is **false**”
  - The knowledge base may be incomplete. The truth of non-derivable axioms is simply unknown.
- DL does ***not*** make the *Closed World Assumption*

Example of how it works in DL

- f1: All *Ducks* have hats
- f2: Bob is a *Duck*
- KB → Bob wears a hat
- But, can Bob fly?
  - We simple do not know!