KGE - Knowledge Graph Engineering

Informal Modelling

Teleology

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ER/EER models - limitations

ER/EER models have three main weaknesses which hugely affect the reuse of data:

- What **situational context** is the ER model modeling? Its spatio-temporal coordinates are left implicit, *as if* the ER model could be used unchanged at all times and in all locations.
- Where do **data and object properties** come from? A theory providing the guidelines for thinking of the possible ways in which entities interact is missing.
- Where do the **extra etypes of the EER model** come from? The step from an ER model and an EER model is completely undefined.

NOTE: The design of ER models is driven by the application. The design of EER models, as extensions of ER models, is driven by the need of quality and of facilitating reuse.

Teleology - Definition

- **Teleologies** are **enriched ER models** with the difference that they are designed to explicitly model the **purpose**:
  1. allow to define the **spatio-temporal context.**
  2. allow to model data and object properties as **objects, functions** and **actions**.
  3. Teleologies (equivalent to ER models) are extended to **teleontologies** (equivalent to EER models) only after the explicit selection of an ontology and with a clear purpose.
- Teleologies provide the basis for a general model for the **heterogeneity of knowledge**.

Teleology - Definition

Teleologies provide the basis for a general model for the **heterogeneity of knowledge** and therefore for knowledge and data reuse.

1. Making explicit the spatio-temporal context allows to make explicit the underlying design assumptions
2. Providing the guidelines for the design of object and data properties allows for a uniform methodology for teleology design
3. The explicit split between costructing teleologies vs. constructing teleontologies allows for large scale data and knowledge reuse

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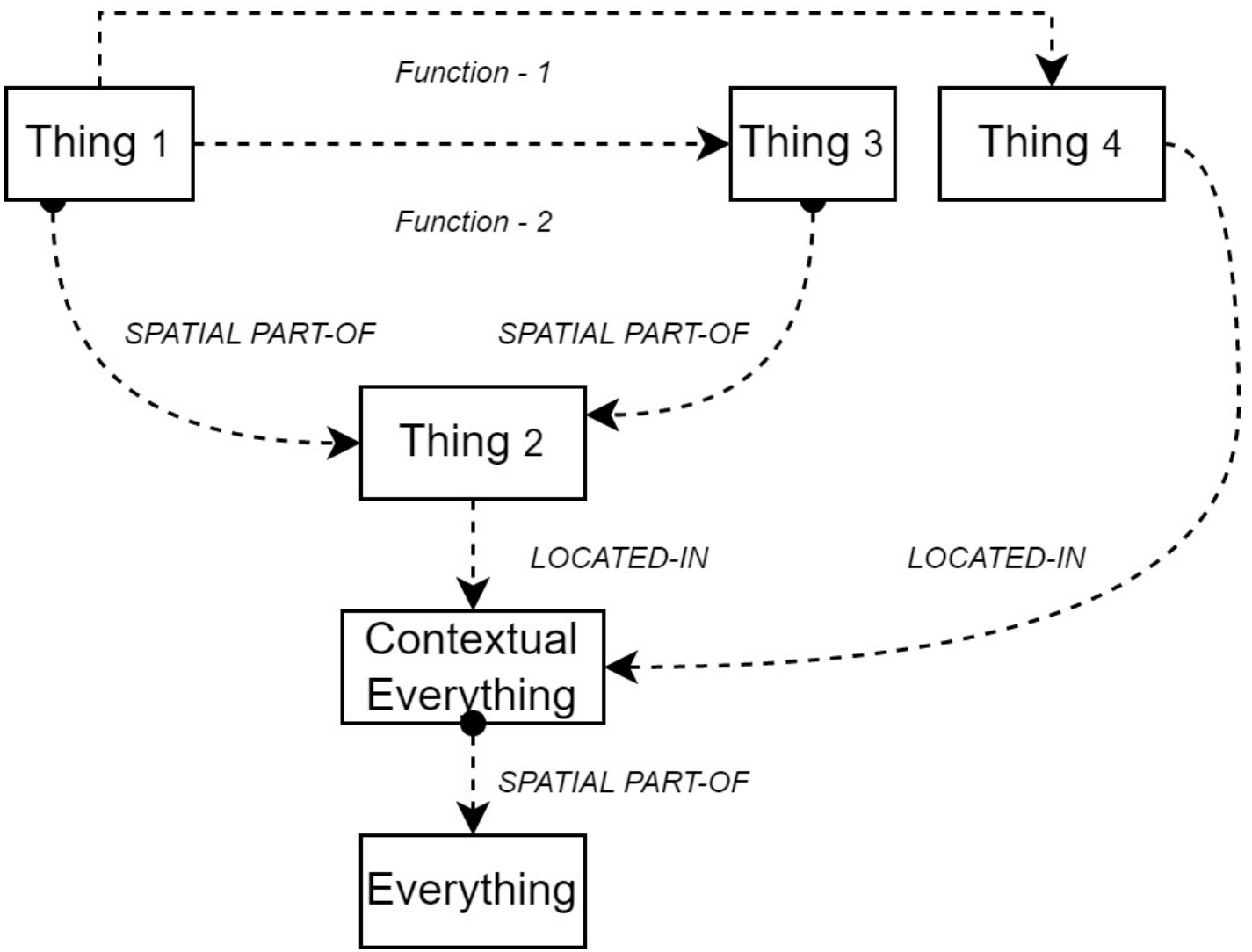
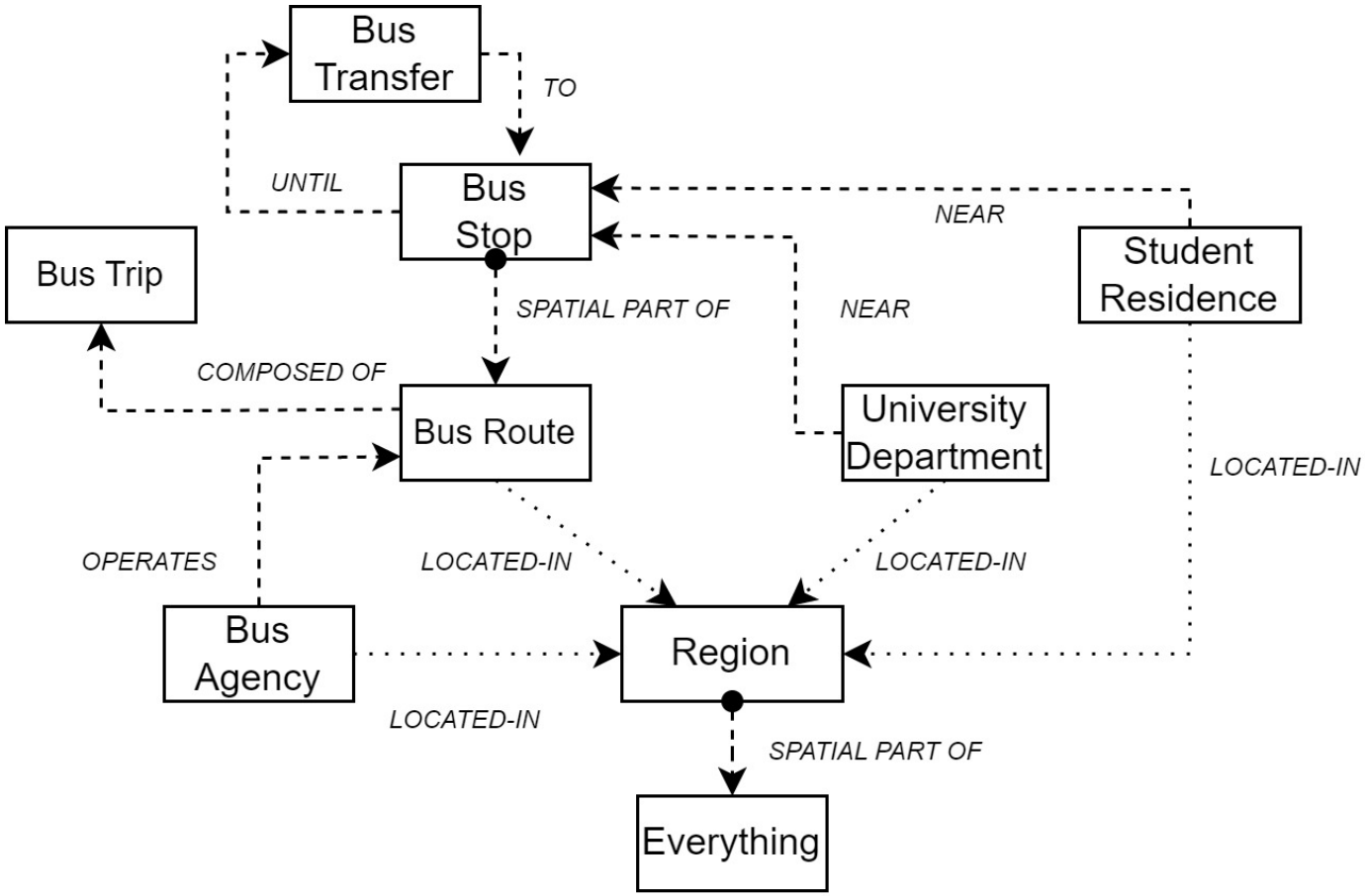
Teleology - General Structure



A Transportation Teleology



TELEOLOGY

Spatial and temporal properties

Space and time are the priors of perception. Everything which we perceive is positioned in space time

- first step is to decide the types of spatio temporal information which is needed
  - Spatial positioning is always needed
  - Spatial relations (e.g., Near, right, left, ..., distance) sometimes not needed
  - Temporal positioning is always needed
  - Temporal relations (e.g., before, after, ...) sometimes not needed (in static applications)
- Define temporal and spatial positioning
- Define spatial relations as needed
- Define temporal relations (e.g., in streams, timestamps).

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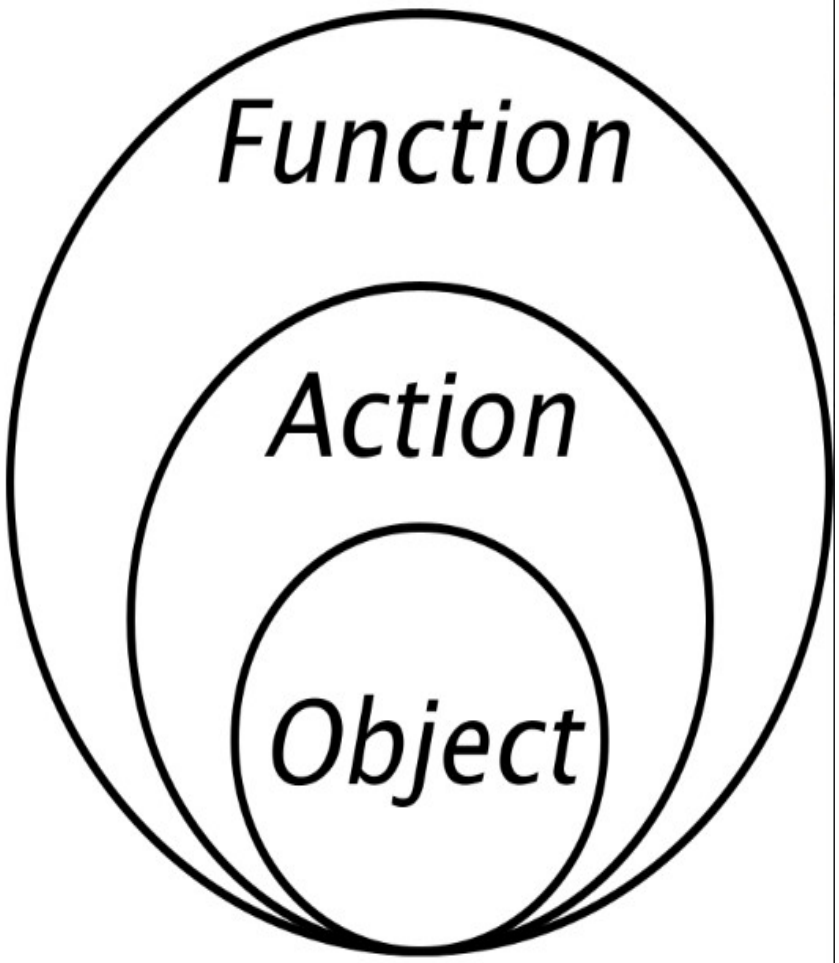
Teleology - Foundations

- A crucial characteristic of humans is their ability to build and exploit representations of what they *perceive* in a **spatio-temporal continuum**.
- We have **objects** which are *representations of what is perceived* (e.g., a car).
- We have **actions**, which *represent how objects change in time* (e.g., move, where, among others, cars can move).
- We have **functions** which *represent the expected behavior of objects* as it is manifested in terms of *a set of actions* (e.g. a vehicle, where, vehicle can perform many actions, e.g., move, stop).

Teleology - Levels of Abstraction

three levels of abstraction

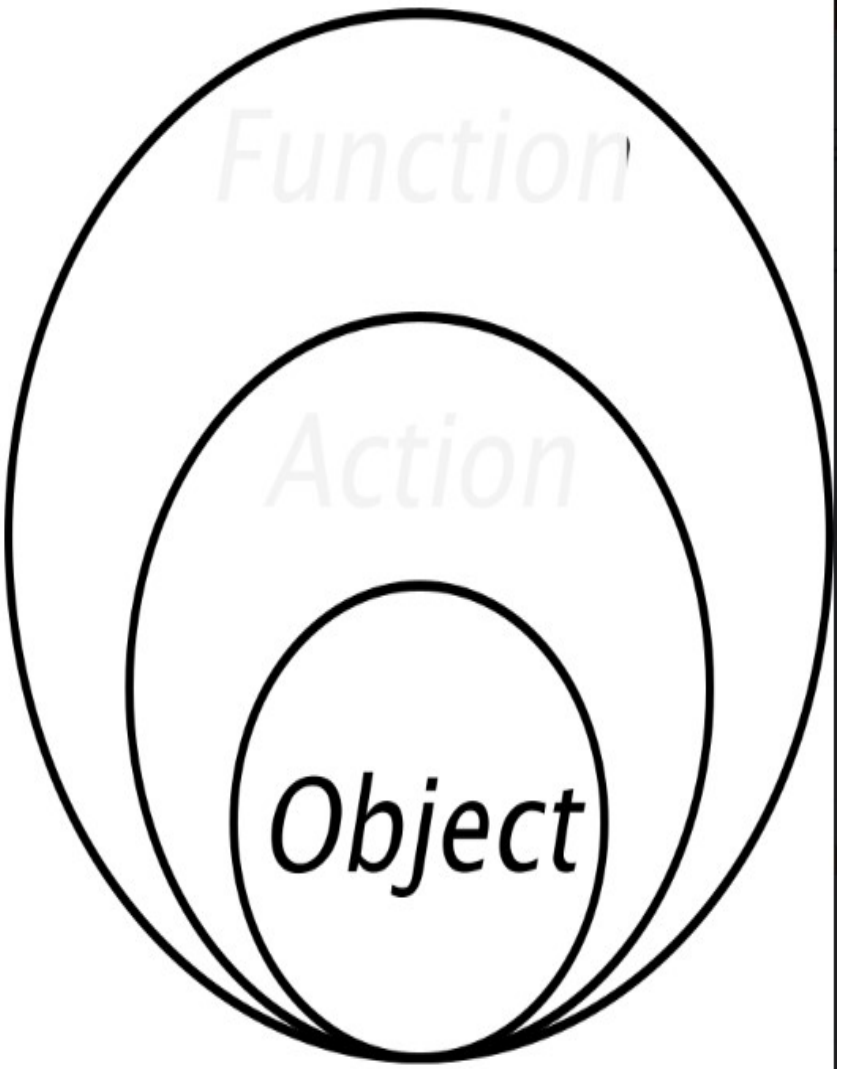
distinction among three types of concepts, namely **objects**, **actions**, and **functions**, which represent what is perceived, across encounters, at increasing levels of abstraction.



Teleology - Object

three levels of abstraction

- An object can be thought as the set of all of the representations of how what is perceived over encounters "fills" space, any time we encounter it.
- Objects can be individuals (what in KR we call instances, e.g., my cat Garfield) or kinds (i.e., generic instances of what in KR we call classes, e.g., any cat that I can encounter while walking).
- Objects are first level abstract representations in the sense that they abstract over multiple occurrences of the same substance (as recognized during encounters) and collect them in clusters (one cluster per object).
- An object, e.g., "a cat", is nothing else but the set of representations of all the times we have perceived (e.g., seen) it.



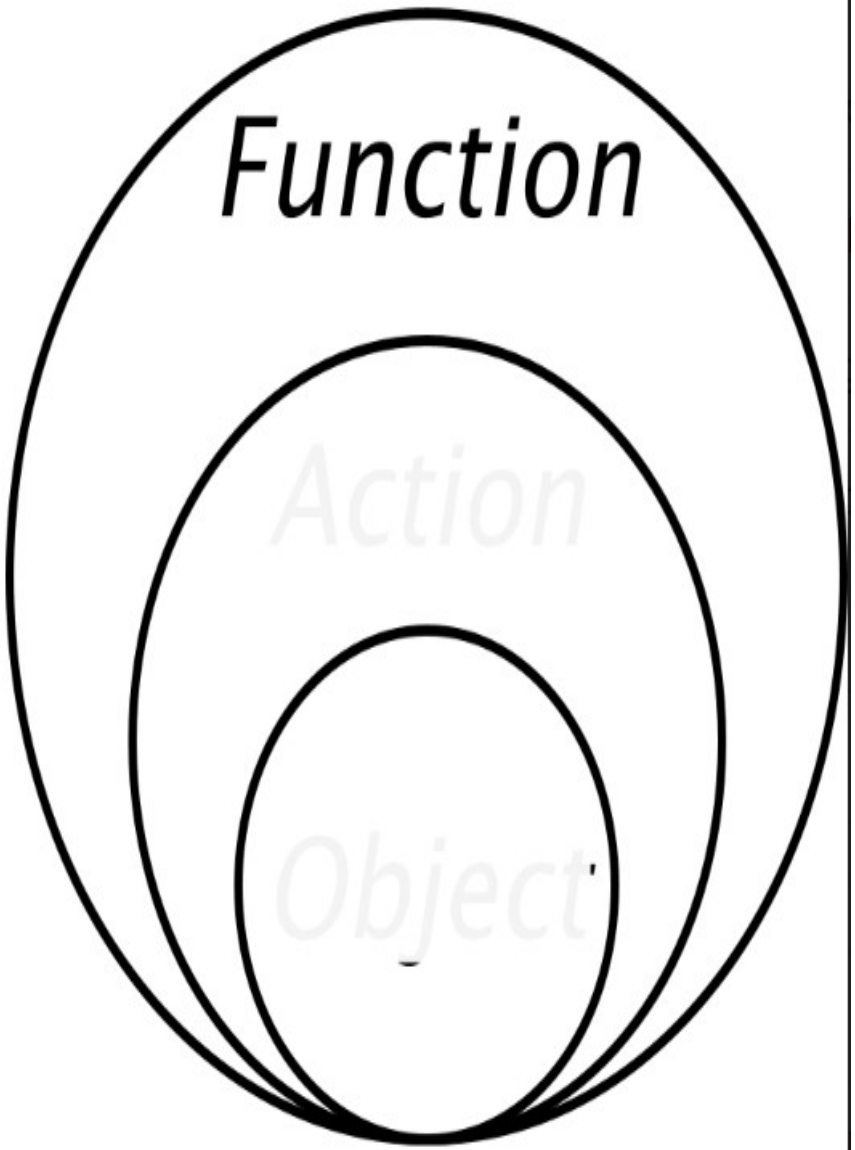
Teleology - Object - Examples

- Person
- Console
- Car
- Building
- Woman

Teleology - Function

three levels of abstraction

- *The function of an object formalizes the behavior that an object is expected to have.* This expected behavior may be due to the object's *purpose* (as it is the case with artifacts, e.g., a car) or to its *role*, for instance in the world and society (as it is the case with living organisms, e.g., a cat, a tree or a person).
- *An object can perform one or more functions*, where a *function is defined as a set of actions*.



Teleology - Function - Examples

- Professor, Student, Patient, Tourist, ... (for **Person**)
- Gaming Console, Virtual Console, ... (for **Console**)
- Vehicle, Cage, Store, ... (for **Car**)
- Hospital, University, Shop, Church, ... (for **Building**)
- Wife, Mother, Businesswoman, ... (for **Woman**)

Producer

- An object plays the *function of a producer* when it performs an action affecting another object
- Examples of producers are:
  - Car w.r.t *'a car transporting a person'.*
  - Professor, Administrative Staff w.r.t *University*
  - Technician, Engineer w.r.t *Work Places, such as Automobile Plant*
  - ...
- Producers are responsible for modelling *cause* in *causality (cause-effect)*
- Producers can be consumers too, depending on the context.

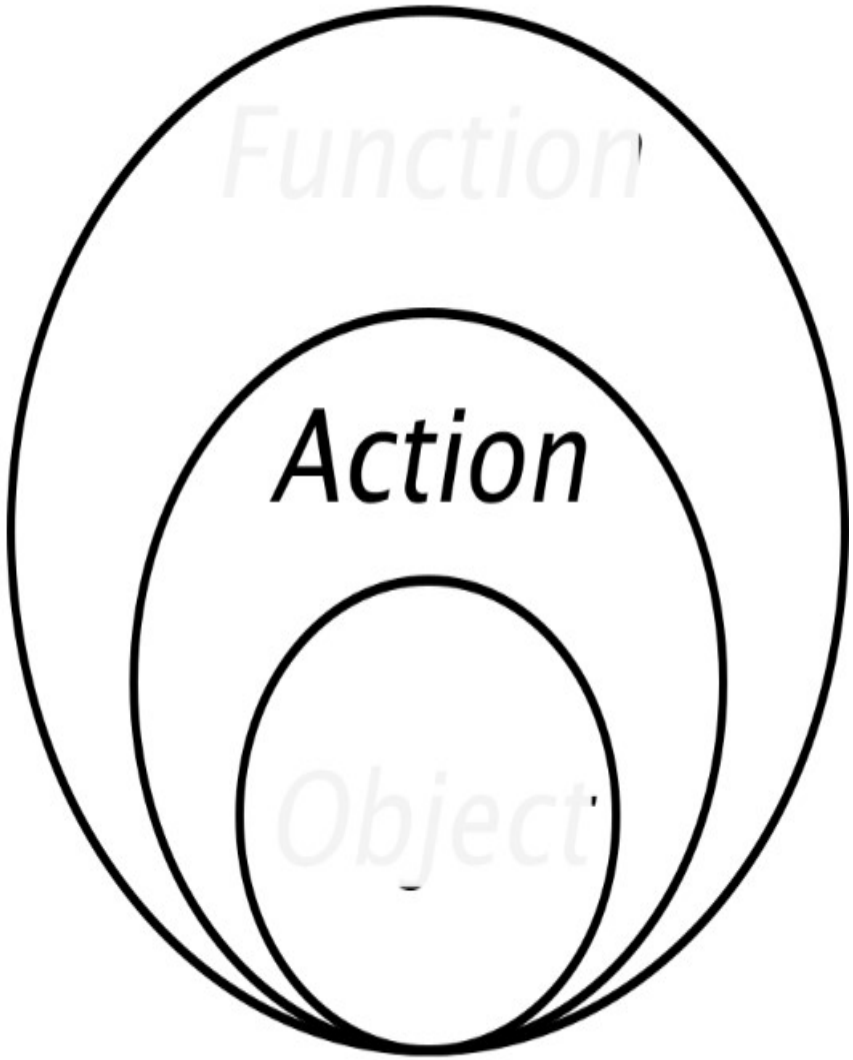
Consumer

- An object plays the *function of a consumer* when it gets affected by an action of another object
- Examples of consumers are:
  - Person w.r.t *'a car transporting a person'.*
  - Students w.r.t *University*
  - Showrooms, Dealers w.r.t *Work Places, such as Automobile Plant*
  - ...
- Consumers are responsible for modelling *effect* in *causality (cause-effect)*
- Consumers can be producers too, depending on the context
- It is important to note that *Producers and Consumers are the foundational constructs which model causality*

Teleology - Action

three levels of abstraction

- We take *Actions* to be those concepts which *represent how objects change in time*. Examples of actions are: running (performed by, e.g., cats), carrying (performed by, e.g., cars) and flowing (performed by, e.g., rivers).
- Actions are *second level abstract representations* in the sense that they abstract over multiple occurrences of changes in time of a substance (as recognized during encounters) and collect them in clusters (one cluster per action).
- An action, e.g., "running", is taken to be the set of representations of all times we have perceived a running object, e.g., "a cat" (or "a dog"), where the representation of "a running cat" or ("a running dog"), is a temporal sequence of "cat" ("dog") occurrences. We say that *a certain object O performs a certain action A* when we perceive O subject to the change described by A.



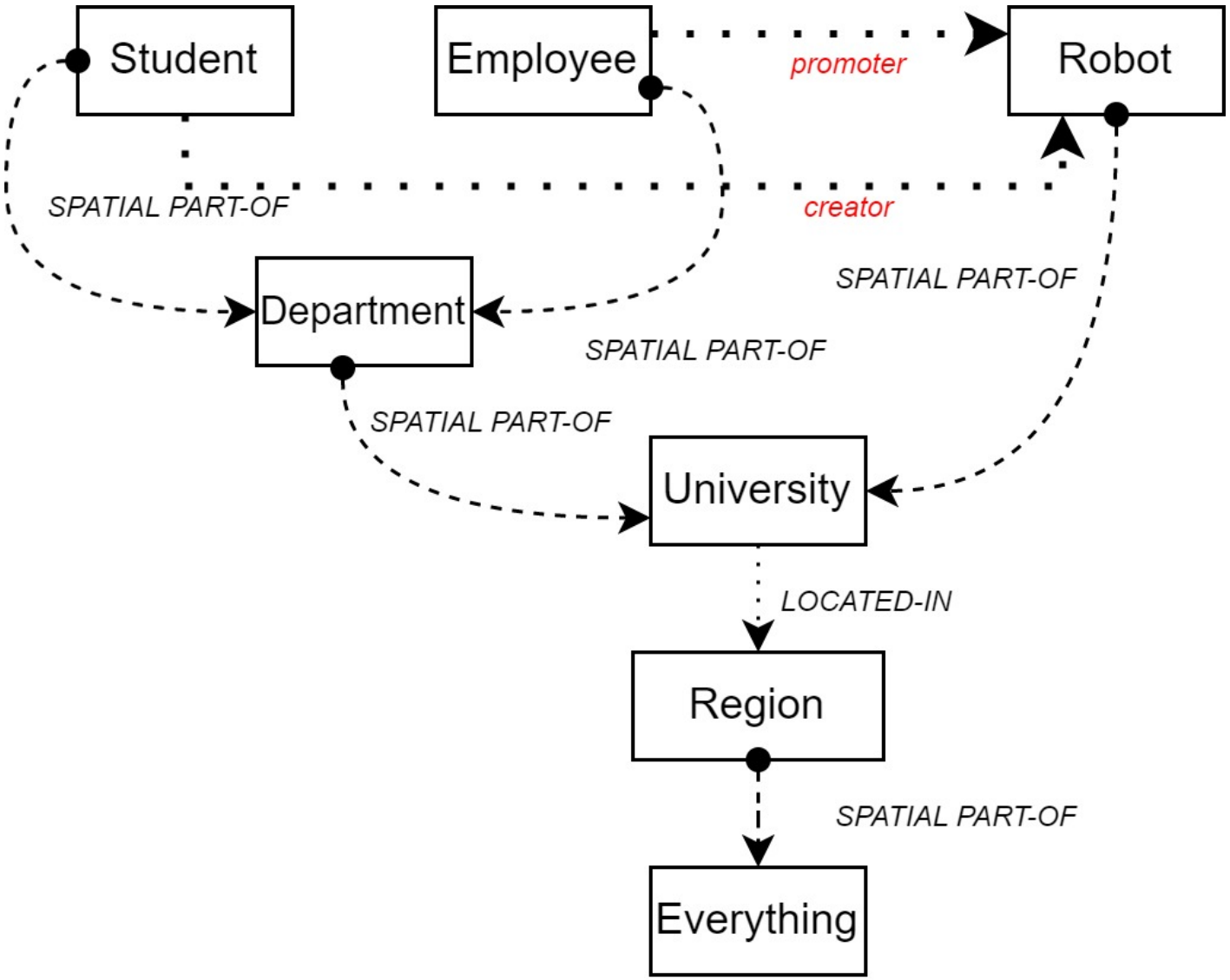
Teleology - Action - Examples

- Supervise Student, Manage Project, Teach Course, ... (for **Professor**)
- Start Game, Stop Game, Increase Life,... (for **Gamer**)
- Accelerate, Stop, Start, ... (for **Vehicle**)
- Provide Bed, Provide Treatment, Provide Medicine, ... (for **Hospital**)
- Chair Meeting, Sign File, Approve Cost, ... (for **Businesswoman**)

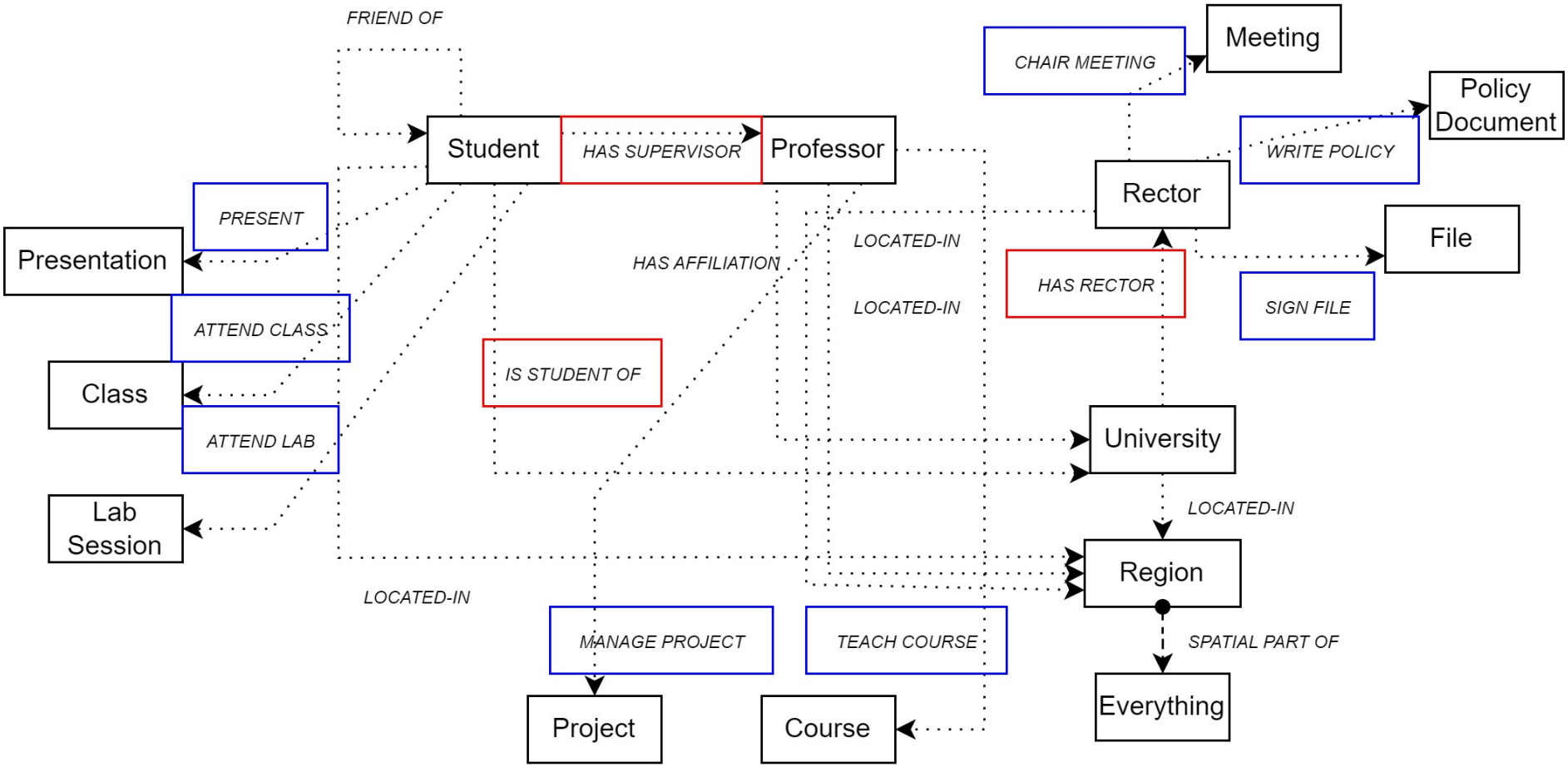
Teleology - (Im)Proper Functions & Actions

- (Im)Proper functions emphasizes the fact that these are functions which are (un)expected for a particular object
- Professor (Proper), Student (Proper), Human Shield (Improper), ... (for **Person**)
- (Im)Proper actions emphasizes the fact that these are actions which are (un)expected for a particular function (corresponding to a particular object)
- Supervise Student (Proper), Teach Course (Proper), Buy Pasta (Improper) ... (for **Professor**)

Teleology (Functions in *Red*)



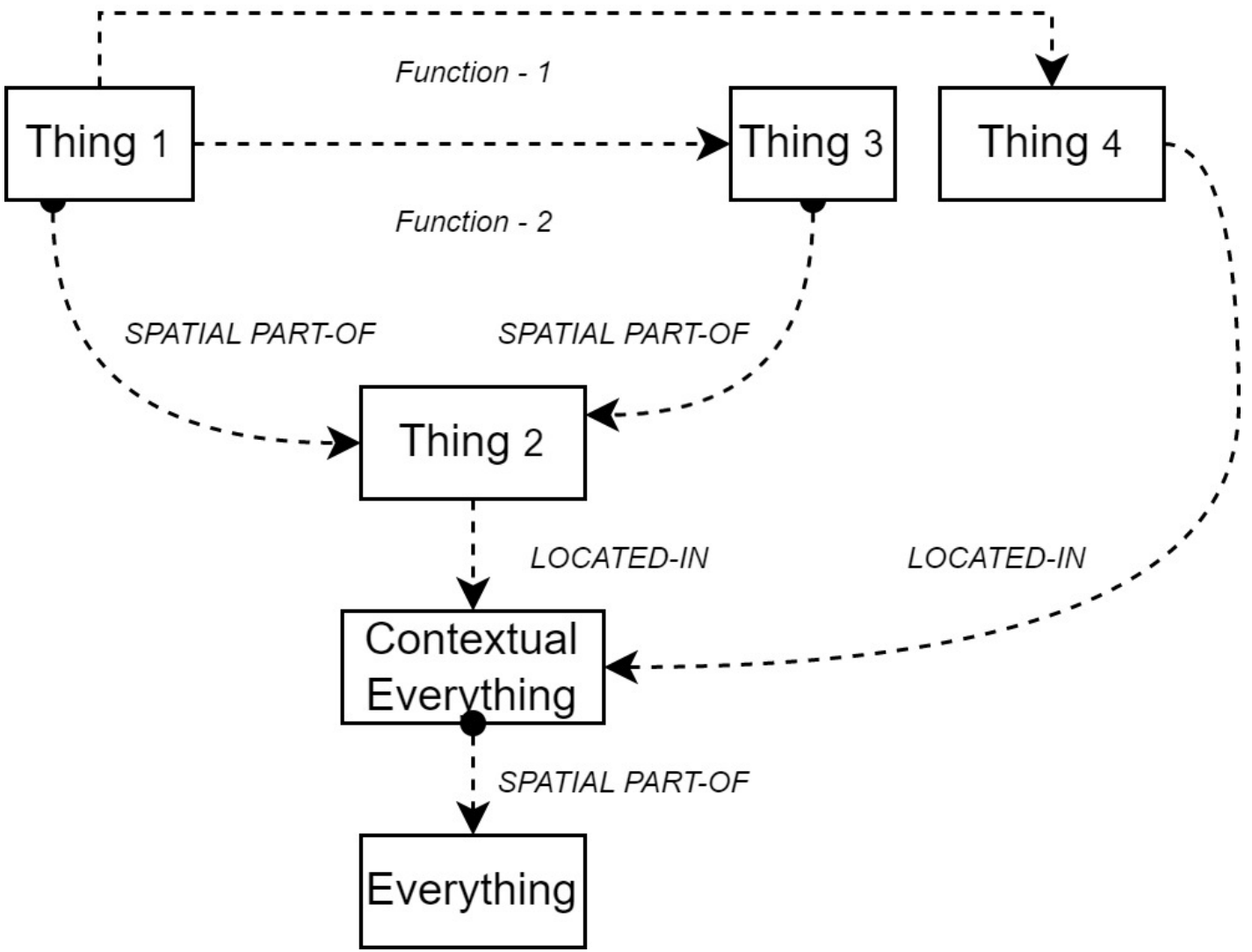
Teleology - Functions + Actions (in *Blue*)



Object and data properties

- Objects are modeled as etypes.
- Functions can be modeled as etypes when we are interested in a specific function. In which case they take the properties of bothe objects and functions (e.g., restaurant)
- Actions can be modeled as etypes, in which case we call them **events** (not considered in this course)
- Functions and actions can be modeled as
  1. object properties
  2. data properties
  3. values (strings) of data properties

Teleology - General Structure



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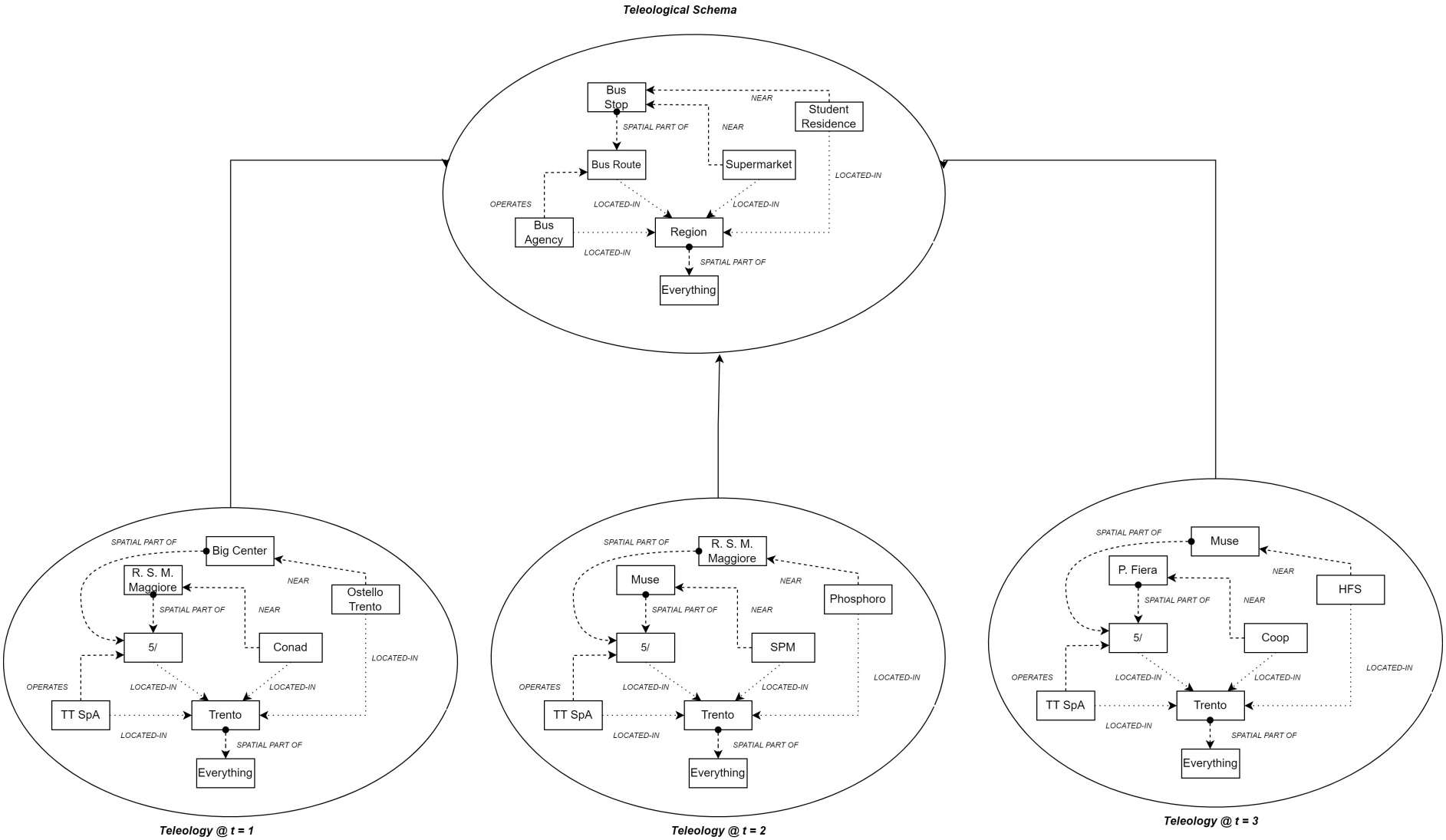
Teleology - Basic streams

- Basic teleological streams are composed of two teleologies which need to be composed at (different) times.
- The first type of teleological streams are built using a teleology which models the **context** in which streams evolve (e.g., Trentino).
- A second teleology models the changes in state of an **actor** (e.g., bus), changing state within the boundaries defined by the reference teleology, (e.g., actions, external state, e.g., position, internal state, e.g., mood of a person or quantity of gas in a bus) in time.
- The two teleologies should be developed independently and then aligned

Teleology - Streams - Example



Teleology - Types of Streams

- **One context - one actor (Basic streams)**: One reference context, one actor (e.g., one or more buses moving around in Trento). An actor may be instantiated to one or more entities;
- **One context - multiple actors**: One reference context, multiple actors (e.g., people taking buses and moving around in Trento);
- **Multiple contexts - one actor**: Multiple reference contexts, one instance of reference context active at the time, one actor (e.g., one or more people during one day of their life, e.g., home, car, work, moving around in Trento).
- **Multiple contexts - multiple actors**: Multiple reference contexts, multiple actors (e.g., people in a community during one day of their life, e.g., home, car, work, moving around in Trento).

Teleology - How to handle Streams

- Teleological streams are snapshots of an underlying teleology in (different) times.
- Teleological streams are built on top of an underlying teleology which models the context (*aka* environment) in which streams are contained.
- The underlying teleology models the static functions of one or more actors (such as a bus)
- Given the function (e.g., bus), the teleological streams model its change in state (i.e. actions) in time.
- For example, the movement of the same bus in different time snapshots.

Teleology - How to handle Streams

- On top of the "usual" difficulties, the issue is that of aligning the data (via timestamps) into multiple timestamped knowledge graphs
- Start by checking the time stamps in the available data and decide how to align data in time stamps. It may need interpolation (adding missing data) or, vice versa, compression (deleting useless data
- Generate a stream with all timestamps (if needed) and import it first.
- Integrate the data streams one at the time

NOTE: the choice on the integration order is application dependent. To be evaluated case by case.

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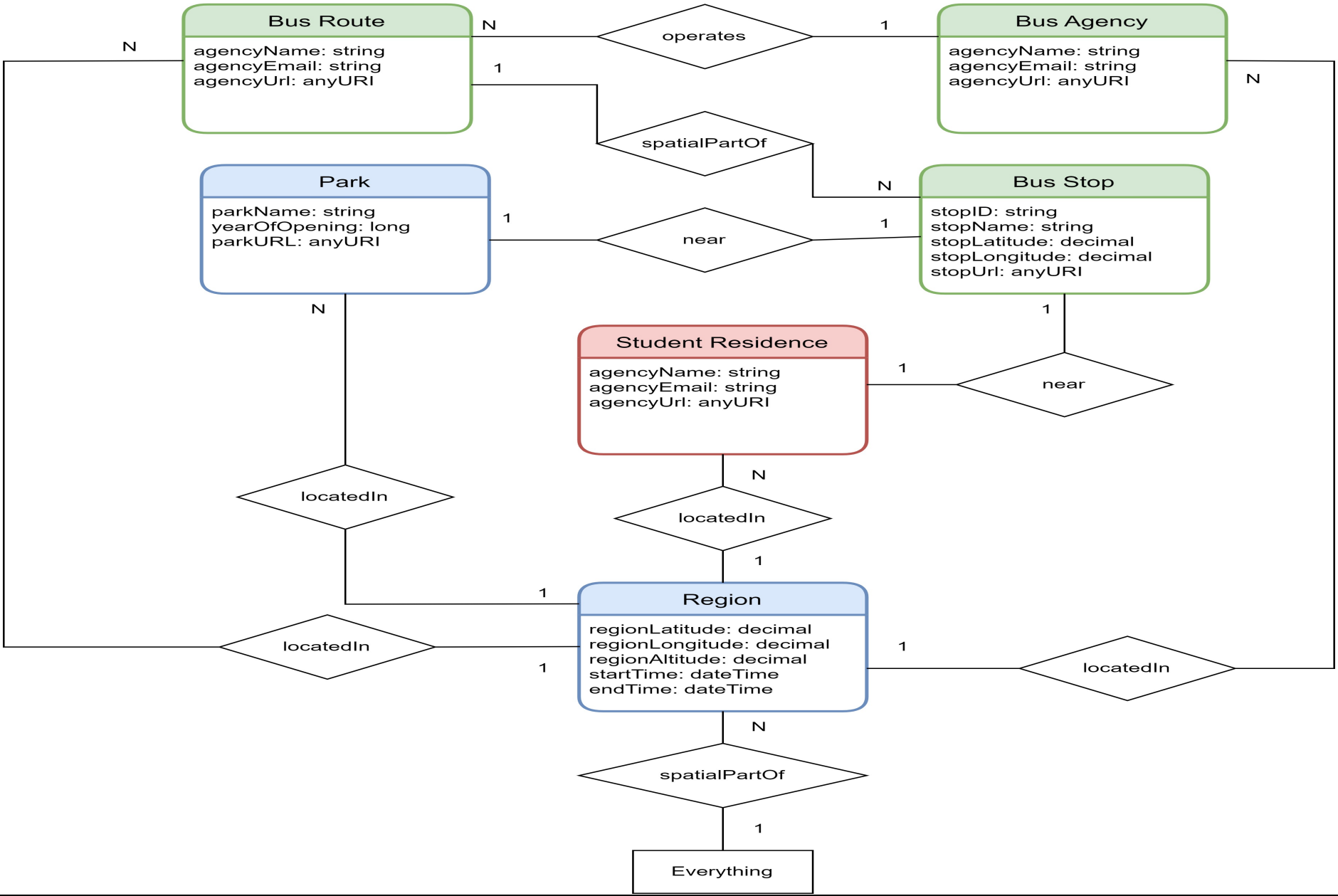

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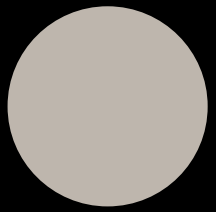
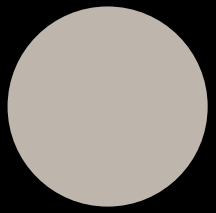
6 **References**

References

- Giunchiglia, Fausto, and Mattia Fumagalli. "Teleologies: Objects, actions and functions." International conference on conceptual modeling. Springer, Cham, 2017.
- Giunchiglia, Fausto, and Mattia Fumagalli. "Concepts as (Recognition) Abilities." In FOIS, pp. 153-166. 2016.

KGE - Knowledge Graph Engineering





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