Applying OntoClean for the Evaluation of the MIP Information Model

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Fraunhofer FKIE develops models, methods and tools for **networked operational Command and Control Systems**.

- **Research Areas**
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  - Communication Systems
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  - Balanced Human Systems Integration
  - Information Technology for Command and Control
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  - Cyber Security
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Locations	Wachtberg and Bonn
Founded	1963
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Multilateral Interoperability Programme

MIP is Interoperability organization of 24 nations, NATO and EDA.

Focus on

- Interoperability of command and control (C2) systems
- Multinational or coalition environments at all levels of command
- Land operational users in a joint environment with growing emphasis on air, maritime, and other communities of interest (CoIs)

Products

- Specifications for operational, technical, and procedural aspects; current version MIP 4 Information Exchange Specifications
- Semantic Reference Model (MIM) for harmonization of different requirements across C2 domain; current version MIM 4.0.1
- Operational and technical test sessions
- Software Development Kits (SDKs) to support national implementations

Overview

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1. The MIP Information Model

- The MIM is a platform-independent information model, based on UML and OCL.

- It is represented in Sparx EA format and supported by a dedicated tool suite (MIM TS, Linked Data Server).

- An OWL2 representation of the MIM as an ontology has been created.

- The MIM serves as a semantic reference for information exchange in joint & combined operations (primarily addressed from land perspective).

- It has been designed with regard to readability, modularity, extensibility, semantic strictness, model consistency. It enables model-driven software development.

- The MIM is successor of the JC3IEDM, derived by more than 30.000 changes.

- It is under continuous development.
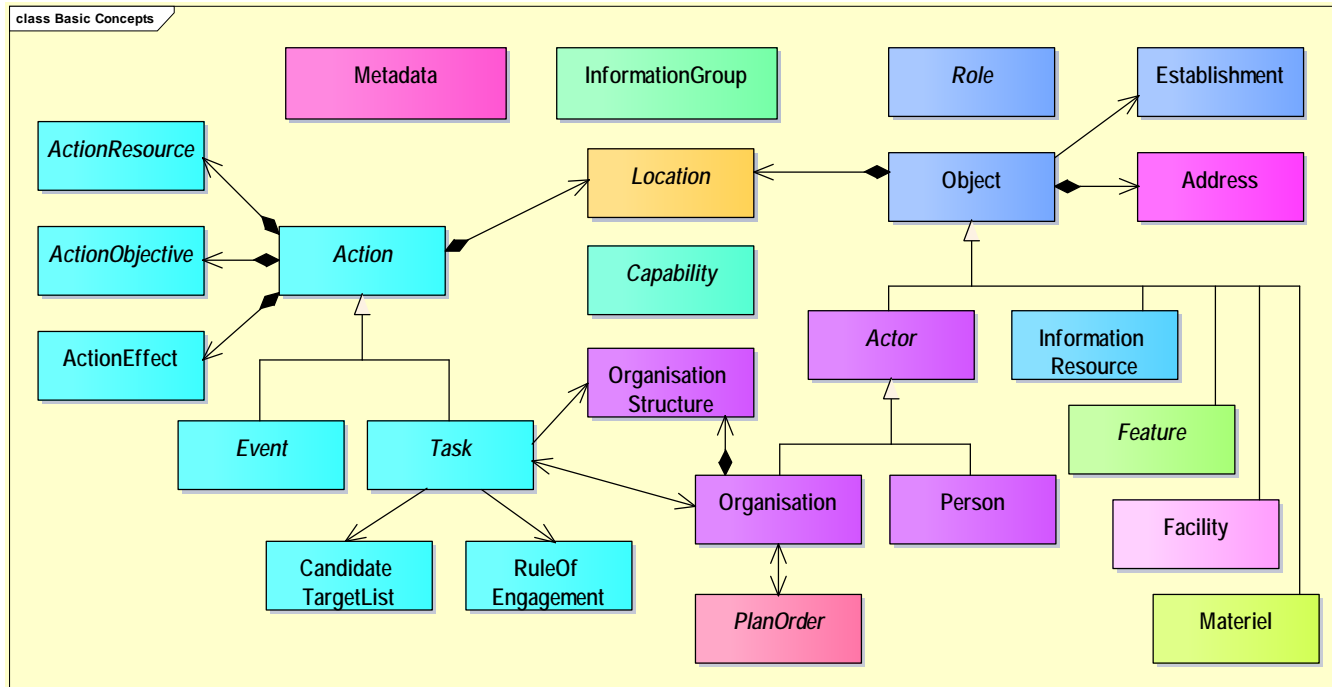
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Scope of the MIM

- Taxonomies of basic concepts like Object, Action etc, incl. attributes and associations
- Approx. 2.300 types of objects, 500 types of actions, 400 code lists, 100 associations
- Roles: roles serve the context-specific characterization of objects. The role-concept is considered fruitful but has not yet been fully exploited within the MIM.

2. Ontology Evaluation with OntoClean

- In the construction of an information model or ontology inconsistencies may occur and most probably will occur.

- In order to avoid and mitigate inconsistencies it suggests itself
  - to guide the ontology construction from the beginning and
  - to evaluate and eventually correct existing parts of the ontology.

- To these ends, criteria for guidance and evaluation are needed. Ideally, these criteria are so general that they can be applied to any arbitrary ontology.

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- **OntoClean has been developed by Guarino and Welty as a general methodology for the evaluation of ontologies, in particular taxonomies.**

- Following OntoClean, classes and other concepts are further specified by meta-properties, namely
  - rigidity,
  - identity,
  - unity, and
  - external dependence

- With reference to these meta-properties, subsumption constraints are defined. It can be tested whether subsumption hierarchies within the given ontology meet these constraints.

- If this is the case, then the ontology can be considered "ontoclean". Otherwise, the ontology is conceptually inconsistent and has to be re-worked.

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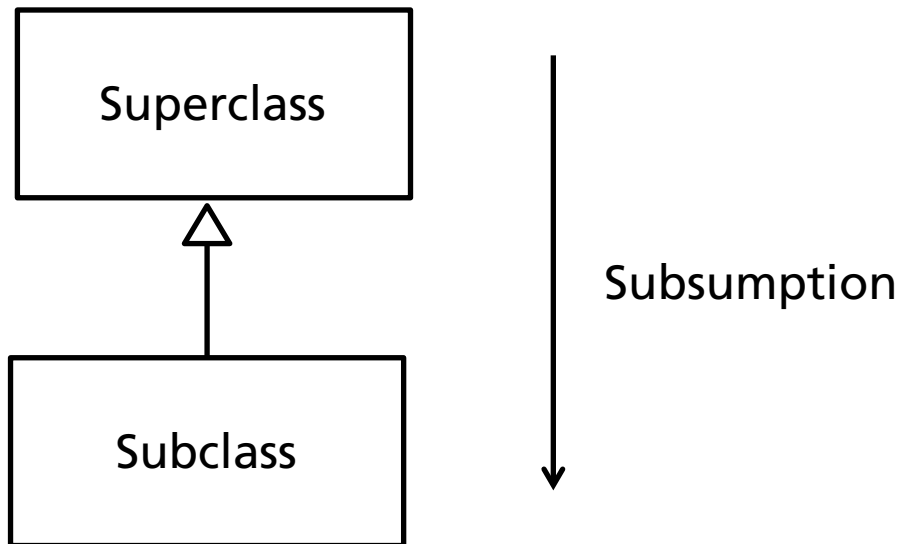
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Subsumption

A class A subsumes a class B if and only if all elements of B are always also elements of A.

In a class model, subsumption is more or less reducible to the subclass relation.

Every class subsumes at least itself and all of its sub-classes.

Annotation and Evaluation

1. View all classes separately and tag them regarding the OntoClean meta-properties.

2. Now view the entire class hierarchy. Do the subsumption hierarchies meet the subsumption constraints imposed by the tagging? Mark problematic cases that lead to inconsistencies.

3. Correct the problematic cases.

   a. If a problematic class is superfluous, remove it.

   b. If you can solve inconsistencies by redefining problematic classes without changing their intended meaning, do so.

   c. Remove the remaining subsumption relations that do not meet the constraints. Connect classes that are now disconnected by relations that do not imply a subsumption.
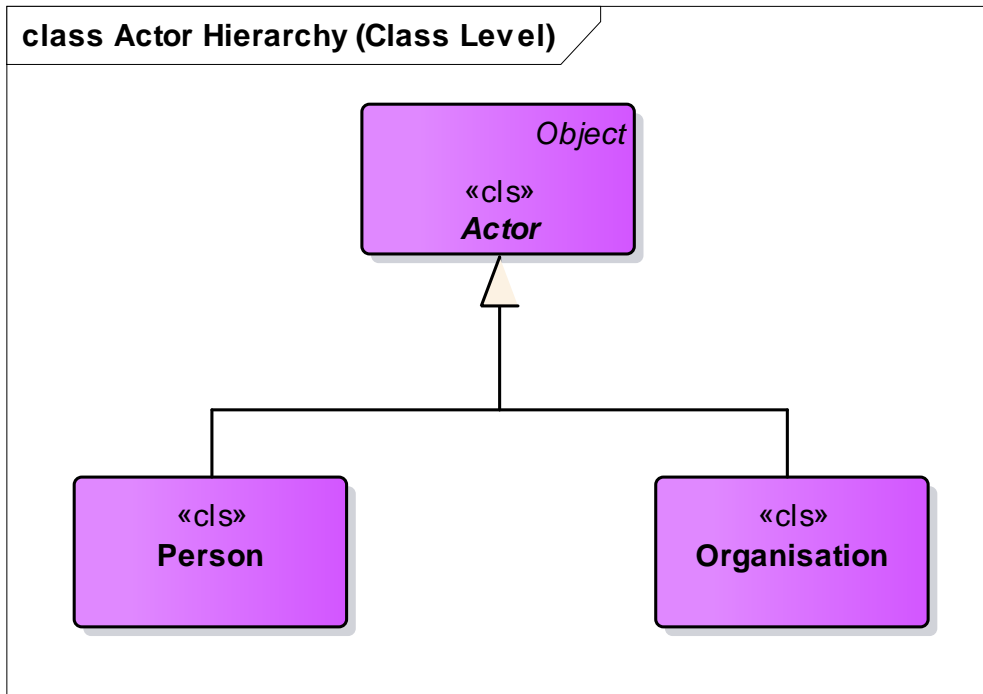
Rigidity

- A class is rigid if and only if the membership to this class is essential, that is, always necessary for all of its elements.

- Rigid classes (+R): e.g. 'Person'

- Anti-rigid classes (~R): membership is not essential for any member of the class; e.g. 'Employee of FKIE' (roles)

- Non-rigid classes (-R): membership is essential for some but not all members of the class; e.g. 'Weapon'

- Subsumption constraint for rigidity: an anti-rigid class (~R) must not subsume a rigid class (+R).

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- Actor: A person or a group of persons that is able to perform actions.

  - Person: A human being of military or civilian significance.

  - Organisation: An administrative or functional structure. Remarks: An Organisation is constituted to accomplish an aim, purpose, or mission.

Identity

- A class carries the meta-property 'identity' if and only if there is a single criterion by which all elements of the class can be stably identified and thus distinguished from each other.

- Identity classes (+I): usually expressed by nouns, e.g. 'Person', 'Group'
- Non-identity classes (-I): usually expressed by adjectives, e.g. 'Red', but also 'Social Entity'

- Subsumption constraint for identity: a class with an identity criterion (+I) cannot subsume a class without an identity criterion (-I) because the subsumed class inherits the identity criterion from the upper class.
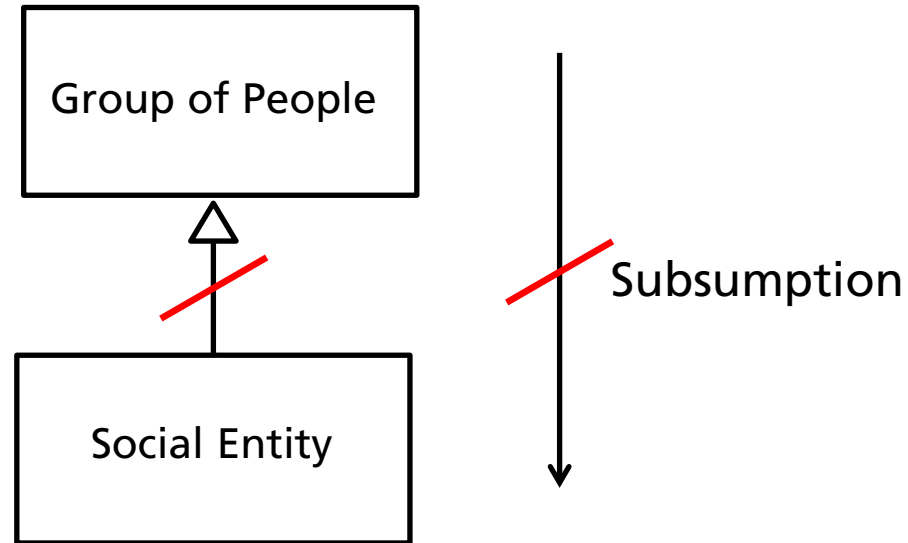
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A social entity **consists of** a group of people but it **is not** a group of people.

Unity and External Dependence

- The unity meta-property serves to distinguish intrinsic wholes (simple and complex objects) from pure amounts of matter.

    - While a river counts a whole carrying the unity meta-property (+U), an amount of water cannot be considered a whole (~U).

    - ~U cannot subsume +U. (If a class does not contain integral wholes then its sub-classes do neither.)

    - A river **is not** an amount of water; it **consists of** an amount of water.

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    - Concept of 'parent' is externally dependent on the concept of 'child', and vice-versa.

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3. Evaluation of the MIM

- For an OntoClean evaluation of the MIM, we tagged the entire object taxonomy by hand.

- We did not determine violations of the subsumption constraints.

- Consequently, we can consider the MIM to be "ontoclean".

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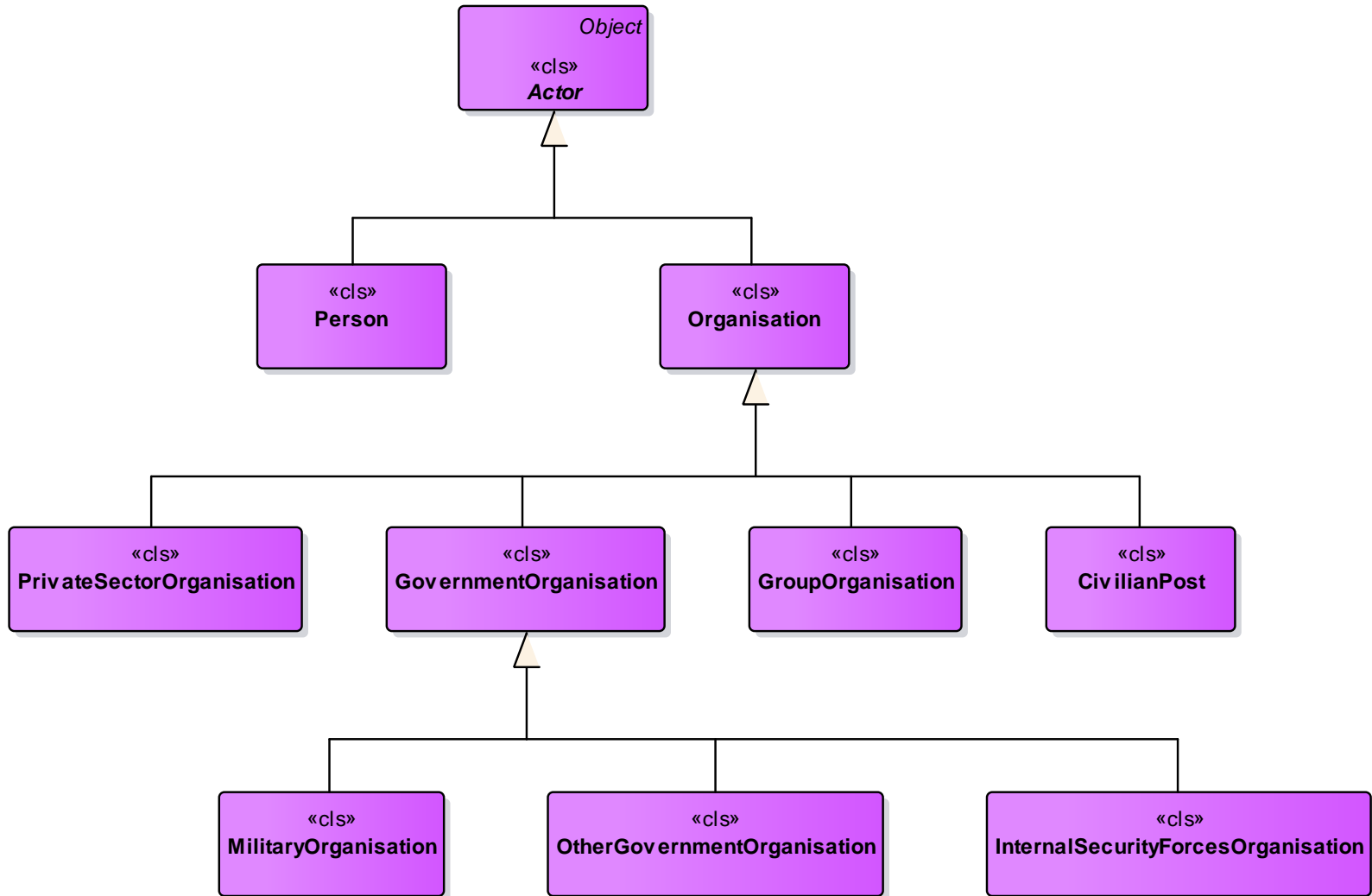
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- Consequently, we can consider the MIM to be "ontoclean".

- However, we were pointed to cases that demand further investigation, in particular regarding the further modelling of roles in MIM.

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class Actor Hierarchy (Class Level)

4. Experiment on OntoClean Tagging

Annotation experiment of Völker et al. (2008) with OntoClean experts revealed a very low agreement of human annotators, close to the random baseline.

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Experiment:

- 7 subject matter (MIM) experts annotate 30 sub-classes of the Facility hierarchy.

- 5 subjects fill out the annotation sheet completely, 2 subjects completed far less than 50 % of their sheets.

Results 1

	Rigidity	Identity	Unity	Dependence	Total
Total agreement	13 %	0 %	30 %	43 %	22 %
Tendency towards a specific value	37 %	17 %	60 %	23 %	34 %
Disagreement	50 %	83 %	10 %	33 %	44 %

Total Agreement

Results 2

	A1/A2	A1/A3	A1/A4	A1/A5	A2/A3	A2/A4	A2/A5	A3/A4	A3/A5	A4/A5	Avg.
Rigidity	69,2%	53,8%	46,2%	58,3%	44,8%	65,6%	57,1%	41,4%	66,7%	25,0%	52,8%
Identity	6,7%	31,0%	50,0%	96,7%	69,0%	56,7%	3,3%	41,4%	27,6%	46,7%	42,9%
Unity	96,7%	93,1%	86,7%	43,3%	89,7%	90,0%	40,0%	86,2%	37,9%	36,7%	70,0%
Depend.	93,3%	48,3%	83,3%	56,7%	55,2%	90,0%	63,3%	58,6%	79,3%	73,3%	70,2%
Avg.	66,5%	56,6%	66,6%	63,8%	64,7%	75,6%	40,9%	56,9%	52,9%	45,4%	55,2%

Pair-Wise Agreement

Fleiss Kappa:

- Rigidity: κ = 0.004
- Identity: κ = -0.151
- Unity: κ = -0.042
- Dependence: κ = 0.434

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Interpretation of Results 1 & 2

Since the inter-annotator agreement is very low, the annotations cannot be considered reliable.

Results 3 and Interpretation

- The OntoClean annotation done by the test subjects entail minor violation of subsumption constraints regarding rigidity, identity and unity.

- These violations do not reveal serious inconsistencies of the MIM. They can rather be attributed to an uncertainty of the proper meaning of the meta-properties and how to apply the OntoClean method.

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5. Conclusions

- Evaluation is a critical task in model development. There are not many general evaluation methodologies (alternatives of OntoClean) on the market.

- The OntoClean methodology itself proofed to be quite difficult to understand and hard to apply which has been demonstrated by an annotation experiment. The outcomes of an OntoClean evaluation, however, are rather small.

- The MIM can be considered "ontoclean" and thus conceptually coherent.

- We were pointed to possible intricacies regarding the modelling of roles that must be kept in mind for the further development of the model.

- We do not recommend the integration of OntoClean into the MIM Tool Suite.

- Still, OntoClean may provide guidance when the modelers cannot agree on the proper representation of concepts. The OntoClean constraints will thus be kept in mind as guidance for the further development of the MIM.

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Thank you.

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BACK UP

Unity

- An intrinsic integral whole under a unifying relation R is an object that is an integral whole under R for all time of its existence. A class carries the meta-property unity (+U) if and only if there exists a common unifying relation by which each element of the class can be seen as an intrinsic integrated whole.

- Unity classes (+U): usually expressed by count nouns, e.g. 'Person', 'River'

- Anti-unity classes (~U): no member is an intrinsic integral whole, usually expressed by count nouns, e.g. 'Amount of Water'

- Non-unity classes (-U): only some members are intrinsic integral wholes, e.g. 'Actor'

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- Subsumption constraints for unity:
  - A class with a unity criterion (+U) cannot subsume a class without a unity criterion (-/~U) because the subsumed class inherits the unity criterion from the super-class.
  - An anti-unity class (~U) subsumes only anti-unity sub-classes (~U): if a class does not contain integral wholes then its sub-classes do neither.
- Amounts of matter cannot subsume objects.

A river **is not** an amount of water; it **consists of** an amount of water.

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External Dependence

- A class A is externally dependent on another class B if and only if for each instance of A there must be a corresponding instance of B.

- Dependent classes (+D): e.g. 'Parent', 'Child'

- Non-dependent classes (-D): e.g. 'Person'

- Subsumption constraints for external dependence: A class carrying the dependence meta-property (+D) cannot subsume a class without the dependence meta-property (-D) because dependence is inherited by the subsumed class.