

# Relational Roles and Qua-entities

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AAAI Fall Symposium – Roles, an interdisciplinary perspective

November 4-6, 2005, Arlington, Virginia

# Goal

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- ▷ Describe and extend two approaches to *relational roles* originally presented in:
  - Guizzardi, G.; Wagner, G., Herre, H. (2004) *On the foundations of UML as an ontology representation language*, EKAW2004.
  - Masolo, C.; Vieu, L.; Bottazzi, E.; Catenacci, C.; Ferrario, R.; Gangemi, A.; Guarino, N. (2004) *Social Roles and their Descriptions*, KR04.
- ▷ Compare the two approaches using the *counting problem* and other connected interesting problems as testbeds.
- ▷ Compare, from the ontological and practical point of view, different ways of understanding qua-entities.

# Relational roles

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- ▷ *Dynamic and Anti-rigid.* Linked to the temporal and modal nature of the relation btw roles and their players:
  - *an entity can play different roles simultaneously,*
  - *an entity can change role,* etc.
- ▷ *Relationally dependent.* Defined by means of a relation involving other properties:

$$R(x_1, \dots, x_n) \rightarrow (P_1(x_1) \wedge \dots \wedge P_n(x_n))$$

$$(S) \quad R_m(x_m) \triangleq \exists x_1, \dots, x_{m-1}, x_{m+1}, \dots, x_n (R(x_1, \dots, x_n))$$

- ▷ *Example:*

$$Enr(x, y) \rightarrow Person(x) \wedge University(y)$$

$$Student(x) \triangleq \exists y (Enr(x, y))$$

## Saturated roles

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- ▷ In the student example, fixing universities, more specific roles can be defined:

$$StudentUntn(x) \triangleq Enr(x, \mathbf{untn})$$

- ▷ *StudentUntn* is a *specialization* of *Student*.
- ▷ **Saturated roles** are roles defined on a  $n$ -ary relation for which  $n - 1$  arguments have been fixed.
- ▷ Instantiations of a relation necessarily have all the arguments fixed, therefore an entity plays a **non**-saturated only indirectly, *via* playing a saturated one.

# First approach

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▷ Originally introduced in:

Guizzardi, G.; Wagner, G., Herre, H. (2004) *On the foundations of UML as an ontology representation language*, EKAW2004.

▷ **Motivation.** Harmonizing two views on roles:

- (i) roles are anti-rigid and relationally dependent unary predicates whose instances are the players;
- (ii) roles are rigid unary predicates whose instances are *adjunct entities* depending on players.

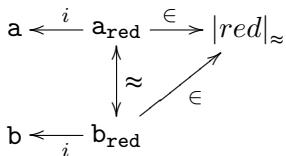
▷ Based on *relational tropes* and *relators*.

# First approach: tropes

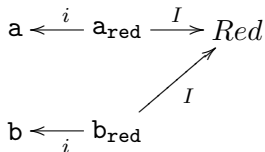
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**Example.** The particulars **a** and **b** have the property “being red”.

Tropes and Maximal classes  
of resembling tropes



Tropes and Universals



*inherence*

$i : \text{trope} \times \text{particular}$

*resemblance*

$\approx : \text{trope} \times \text{trope}$

*membership*

$\in : \text{trope} \times \text{class}$

*instantiation*

$I : \text{trope} \times \text{universals}$

## First approach: relators

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**Example.**  $a$  and  $b$  are in the (binary) relation  $R$ .

▷ *First idea.* Generalizing the approach used for unary properties:

$$\begin{array}{ccc} a & \xleftarrow{i} & r_{a,b} \\ & \nearrow i & \\ b & & \end{array} \quad \xrightarrow{\in} \quad |r|_{\approx}$$

$$\begin{array}{ccc} a & \xleftarrow{i} & r_{a,b} \\ & \nearrow i & \\ b & & \end{array} \quad \xrightarrow{I} \quad R$$

# First approach: relators + relational tropes

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**Example.**  $a$  and  $b$  are in the (binary) relation  $R$ .

▷ *Second idea.* Add to the relator, the *relational tropes* ‘supporting’ unary predicates defined, following (S), by  $R$ :

- “the  $a$ ’s being in relation  $R$  with  $b$ ” ( $a \xrightarrow[r]{R} b$ )
- “the  $b$ ’s being in relation  $R$  with  $a$ ” ( $b \xleftarrow[r]{R} a$ )
- “the  $a$  and  $b$ ’s being in relation  $R$ ” ( $r_{a,b}$ )  
(could be seen as a ‘sum/composition’ of the first two)

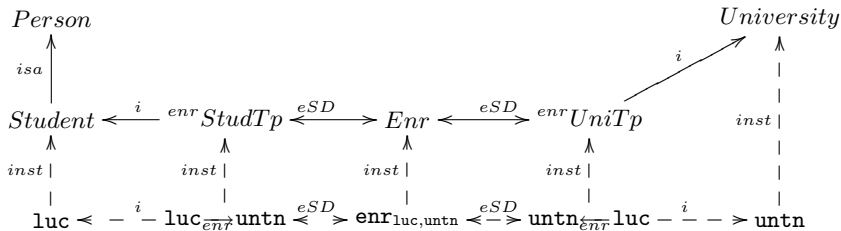
$$\begin{array}{ccccc}
 RArg_1Tp & \xleftrightarrow{eSD} & R & \xleftrightarrow{eSD} & RArg_2Tp \\
 \uparrow & & \uparrow & & \uparrow \\
 inst & | & inst & | & inst \\
 | & & | & & | \\
 a \leq - \overset{i}{-} - a \xrightarrow[r]{R} b & \xleftrightarrow{eSD} & r_{a,b} & \xleftrightarrow{eSD} & b \xleftarrow[r]{R} a - \overset{i}{-} - b
 \end{array}$$



# First approach: roles

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- ▷ Roles are represented as *predicates* specializing *kinds* of particulars (that are neither relational tropes, nor relators) on which relational tropes inhere in.
- ▷ Representation of the student example (where “enrolling university” is not considered a role).



## Second approach

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▷ Originally introduced in:

Masolo, C.; Vieu, L.; Bottazzi, E.; Catenacci, C.; Ferrario, R.; Gangemi, A.; Guarino, N. (2004) *Social Roles and their Descriptions*, KR04.

▷ **Motivation.** Representation of *social concepts* (and social roles) and the conventions/contexts that define them.

▷ Based on a clear distinction between:

▷ properties and relations in the *ground ontology* (static, rigid, extensional, and acontextual predicates);

▷ properties (concepts) *reified* at the object level.

▷ *Extension:* reification of (socially defined) *relations*.

## Second approach: primitives

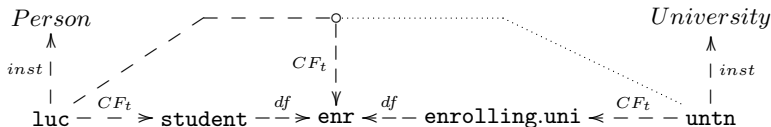
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- ▷  $\text{DF}(x, y)$ : “*concept/relation*  $x$  is defined by *description*  $y$ ”;
- ▷  $\text{US}(x, y)$ : “*concept/relation*  $x$  is used by *description*  $y$ ”;  
i.e.  $x$  can be defined by  $y$  or just ‘imported’ by it;
- ▷  $\text{df}(x, y)$ : “(relational) *concept*  $x$  is defined by *relation*  $y$ ”;  
specialization of DF linking a unary property to the relation on the basis of which it is defined following schema (S);
- ▷  $\text{CF}(x_1, \dots, x_n, y, t)$ : “at time  $t$ , individuals  $x_1, \dots, x_n$  are classified by *concept/relation*  $y$ ”  
( $n = 1$  for concepts,  $n > 1$  for relations)

## Second approach: roles

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- ▷ The anti-rigidity, dynamicity, and relational dependence of roles is defined on the basis of the primitives introduced before.
- ▷ Representation of the student example (assuming that *Person* and *University* are predicates in the ground ontology):



## Second approach: qua-individuals (1)

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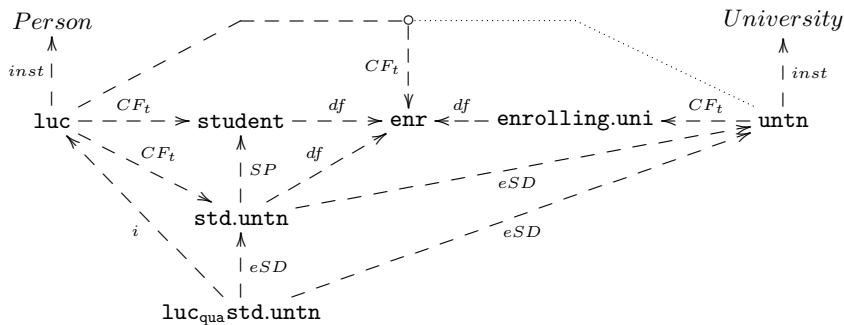
**Motivation.** To cope with classical problems (e.g. the ‘counting problem’).

**Example:** Luc qua student of the university of Trento attends classes punctually, while Luc qua student of the yoga school doesn’t.

- ▷ They exist when an entity is classified by a *saturated* role, therefore they existentially depend on this role (“being enrolled in the University of Trento”).
- ▷ Inherent to the classified entity (Luc).
- ▷ Existentially dependent on all the entities jointly classified by the relation defining the role (University of Trento).

## Second approach: qua-individuals (2)

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# The counting problem

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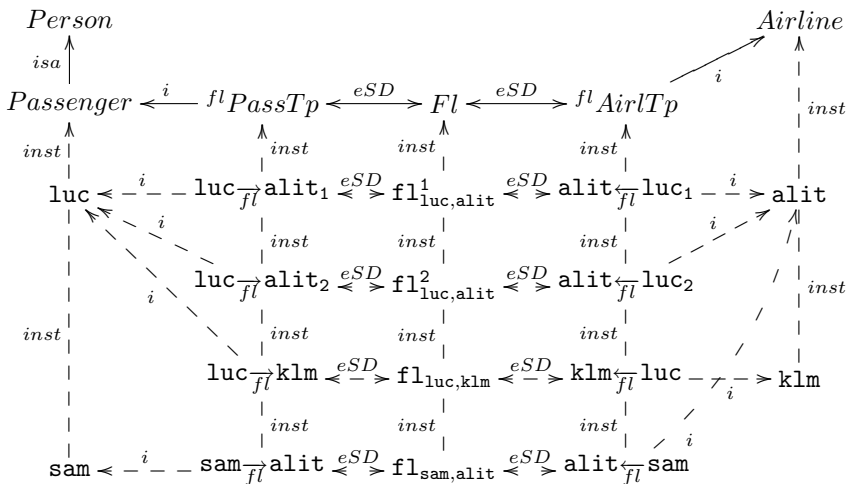
- ▷ Originally formulated by A. Gupta in 1980:
  - Alitalia served one million passenger in 2004
  - Every passenger is a person
  - Ergo, Alitalia served one million persons in 2004.
- ▷ If a given person flew several times Alitalia in 2004, the conclusion is false.
- ▷ Therefore, to count passenger we cannot just count persons.
- ▷ So, what do we count?

**Hypothesis.** Passenger is based on the ‘flies’ relation ( $Fl$ ):

$$Fl(x, y) \rightarrow (Person(x) \wedge Airline(y))$$

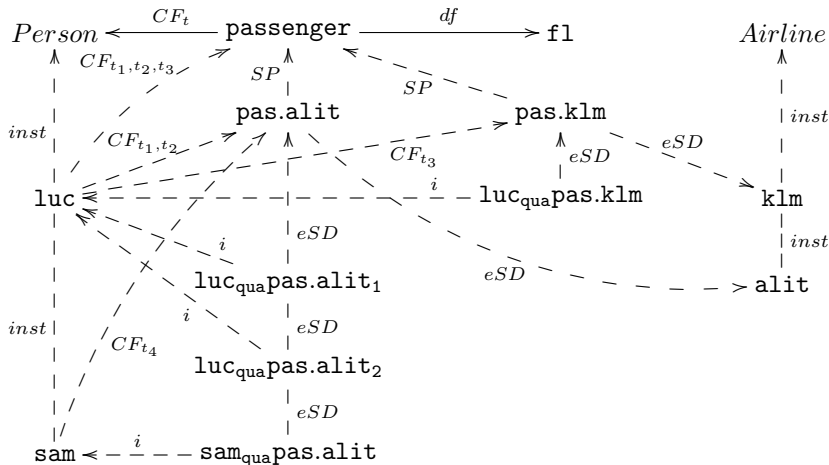
$$Passenger(x) \triangleq \exists y(Fl(x, y))$$

## The counting problem: first approach





# The counting problem: second approach



# Temporal aspects

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- ▷ Both approaches assume two different entities ( $\text{luc}_{\overrightarrow{fl}}\text{alit}_1$ ,  $\text{luc}_{\overrightarrow{fl}}\text{alit}_2$  and  $\text{luc}_{\text{qua}\text{pas}}\text{alit}_1, \text{luc}_{\text{qua}\text{pas}}\text{alit}_2$ ) to represent the fact that Alitalia served Luc “twice”.
- ▷ Both approaches interpret “twice” as “at two different times”, i.e. they consider  $Fl$  as a temporary (and therefore ternary) relation. Different qua-entities correspond to different facts:

$$\begin{aligned}\text{luc}_{\overrightarrow{fl}}\text{alit}_1, \text{luc}_{\text{qua}\text{pas}}\text{alit}_1 &\rightsquigarrow Fl(\text{luc}, \text{alit}, t_1) \\ \text{luc}_{\overrightarrow{fl}}\text{alit}_2, \text{luc}_{\text{qua}\text{pas}}\text{alit}_2 &\rightsquigarrow Fl(\text{luc}, \text{alit}, t_2)\end{aligned}$$

- ▷ Qua-entities are in time and differ by their temporal extension:  
$$\begin{aligned}\text{ext}_T(t_1, \text{luc}_{\overrightarrow{fl}}\text{alit}_1) \wedge \text{ext}_T(t_2, \text{luc}_{\overrightarrow{fl}}\text{alit}_2) \\ \text{ext}_T(t_1, \text{luc}_{\text{qua}\text{pas}}\text{alit}_1) \wedge \text{ext}_T(t_2, \text{luc}_{\text{qua}\text{pas}}\text{alit}_2)\end{aligned}$$

## Relational tropes vs. qua-individuals

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What is the difference between  $\text{luc}_{\overrightarrow{\text{ent}}} \text{untn}$  (*relational trope*) and  $\text{luc}_{\text{qua}} \text{std.untn}$  (*qua-individual*)?

Both inhere in  $\text{luc}$  and depend on  $\text{untn}$ , but:

- ▷  $\text{luc}_{\overrightarrow{\text{ent}}} \text{untn}$  represents the ‘complex’ of all the individual properties that  $\text{luc}$  has by virtue of playing the role “being a student of  $\text{untn}$ ”

while

- ▷  $\text{luc}_{\text{qua}} \text{std.untn}$  is the ‘amalgam’ of  $\text{luc}$  and all the individual properties he has by virtue of playing the role “being a student of  $\text{untn}$ ”.

# Participation

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Let's suppose that `luc` *participates* to a meeting with all the rights, obligations, etc., given by the role “being a student of `untn`”, i.e. he participates *qua* student of the `untn`.

How is it possible to represent this *qualified* participation?

- ▷ *First approach.* Relational tropes (as complexes of individuals properties) cannot participate: `luc` participates to the meeting in a specific way coded by an additional argument (the trope):

$$\text{PC}(\text{luc}, \text{meet}, \text{luc}_{\overrightarrow{\text{ent}}} \text{untn})$$

- ▷ *Second approach.* `luc` with all his student properties (the *qua*-individual, not just `luc`) participates to the meeting, therefore the participation is a binary relation:

$$\text{PC}(\text{luc}_{\text{qua}} \text{std.untn}, \text{meet})$$

## Conflicting properties

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Let's suppose that `luc` is *good qua* student of `untn` but he is *bad qua* student of `unipd`.

Similarly to the case of participation:

- ▷ *First approach.* Only `luc` can be good or bad, not relational tropes, therefore assuming that *Good* and *Bad* are conflicting properties, they need to be qualified by an additional argument:

$Good(luc, luc_{\overrightarrow{enr}}untn) \wedge Bad(luc, luc_{\overrightarrow{enr}}unpd)$   
(*problem:* which properties/relations need to be qualified?)

- ▷ *Second approach.* We can directly apply the properties to the two different qua-individuals:

$Good(luc_{qua}std.untn) \wedge Bad(luc_{qua}std.unipd)$

# Conclusions

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- ▷ The two approaches solve classical problems linked to roles, in addition
  - the first approach harmonize the anti-rigid view and the rigid types of “adjunct entities” one;
  - the second approach introduces the social dimension and consider the specialization relation to create a hierarchy among roles based on levels of generality.
- ▷ The introduction of qua-entities (relational tropes or qua-individuals) is essential to solve the counting problem.
- ▷ The analysis of relational roles puts new light on the ontological nature of qua-entities (present in philosophy since Aristotle).