Relational Roles and Qua-entities

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Goal

▷ 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

▷ *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:

$$R(x_1, \ldots, x_n) \to (P_1(x_1) \wedge \ldots \wedge P_n(x_n))$$

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

▷ *Example*:

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

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

Saturated roles

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

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

- $StudentUntn$ 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 role only indirectly, *via* playing a saturated one.

First approach

- ▷ 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

Example. Particulars $\mathtt{a}$ and $\mathtt{b}$ have the property of “being red”.

Tropes and Maximal classes of resembling tropes

$$\begin{tikzcd}
\mathtt{a} & \mathtt{a}_{\mathtt{red}} \arrow[l, "i"'] \arrow[r, "\in"] \arrow[d, leftrightarrow, "\approx"] & {|red|_{\approx}} \\
\mathtt{b} & \mathtt{b}_{\mathtt{red}} \arrow[l, "i"] \arrow[ur, "\in"'] &
\end{tikzcd}$$

Tropes and Universals

$$\begin{tikzcd}
\mathtt{a} & \mathtt{a}_{\mathtt{red}} \arrow[l, "i"'] \arrow[r, "I"] & Red \\
\mathtt{b} & \mathtt{b}_{\mathtt{red}} \arrow[l, "i"] \arrow[ur, "I"'] &
\end{tikzcd}$$

inherence	$i:$ trope $\times$ particular
resemblance	$\approx$: trope $\times$ trope
membership	$\in$: trope $\times$ class
instantiation	$I:$ trope $\times$ universal

First approach: relators

Example. $\mathtt{a}$ and $\mathtt{b}$ are in the (binary) relation R.

$\triangleright$ *First idea.* Generalize the approach used for unary properties:

$$\begin{tikzcd}
\mathtt{a} & \mathtt{r}_{\mathtt{a},\mathtt{b}} \arrow[l, "i"'] \arrow[dl, "i"'] \arrow[r, "\in"] & \left|r\right|_{\approx} \\
\mathtt{b} & &
\end{tikzcd}
\qquad
\begin{tikzcd}
\mathtt{a} & \mathtt{r}_{\mathtt{a},\mathtt{b}} \arrow[l, "i"'] \arrow[dl, "i"'] \arrow[r, "I"] & R \\
\mathtt{b} & &
\end{tikzcd}$$

First approach: relators + relational tropes

Example. $\mathtt{a}$ and $\mathtt{b}$ are in the (binary) relation R.

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

- "$\mathtt{a}$'s being in relation R with $\mathtt{b}$" ($\mathtt{a}\underset{r}{\rightarrow}\mathtt{b}$)
- "$\mathtt{b}$'s being in relation R with $\mathtt{a}$" ($\mathtt{b}\underset{r}{\leftarrow}\mathtt{a}$)
- "$\mathtt{a}$ and $\mathtt{b}$'s being in relation R" ($\mathtt{r}_{\mathtt{a},\mathtt{b}}$)
  (could be seen as a 'sum/composition' of the first two)

$$\begin{tikzcd}
 & {}^{R}Arg_1Tp \arrow[rr, leftrightarrow, "eSD"] & & R \arrow[rr, leftrightarrow, "eSD"] & & {}^{R}Arg_2Tp & \\
\mathtt{a} & \mathtt{a}\underset{r}{\rightarrow}\mathtt{b} \arrow[l, dashed, "i"'] \arrow[u, dashed, "inst"] \arrow[rr, dashed, leftrightarrow, "eSD"] & & \mathtt{r}_{\mathtt{a},\mathtt{b}} \arrow[u, dashed, "inst"] \arrow[rr, dashed, leftrightarrow, "eSD"] & & \mathtt{b}\underset{r}{\leftarrow}\mathtt{a} \arrow[u, dashed, "inst"] \arrow[r, dashed, "i"] & \mathtt{b}
\end{tikzcd}$$

First approach: roles

- ▷ Roles are represented as *predicates* specializing *kinds* of particulars (that are neither relational tropes, nor relators) in which relational tropes inhere.

- ▷ Representation of the student example (where “enrolling university” is not considered a role).

$$
\begin{tikzcd}
Person & & & & University \\
Student \arrow[u, "isa"] & {}^{enr}StudTp \arrow[l, "i"'] \arrow[r, leftrightarrow, "eSD"] & Enr \arrow[r, leftrightarrow, "eSD"] & {}^{enr}UniTp \arrow[ur, "i"] & \\
\mathtt{luc} \arrow[u, dashed, "inst"] & \mathtt{luc}_{\overrightarrow{enr}}\mathtt{untn} \arrow[l, dashed, "i"'] \arrow[u, dashed, "inst"] \arrow[r, dashed, leftrightarrow, "eSD"] & \mathtt{enr}_{\mathtt{luc},\mathtt{untn}} \arrow[u, dashed, "inst"] \arrow[r, dashed, leftrightarrow, "eSD"] & \mathtt{untn}_{\overleftarrow{enr}}\mathtt{luc} \arrow[u, dashed, "inst"] \arrow[r, dashed, "i"] & \mathtt{untn} \arrow[uu, dashed, "inst"]
\end{tikzcd}
$$

Second approach

- 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

- ▷ $\mathsf{DF}(x, y)$: "*concept/relation* x is defined by *description* y";
- ▷ $\mathsf{US}(x, y)$: "*concept/relation* x is used by *description* y";

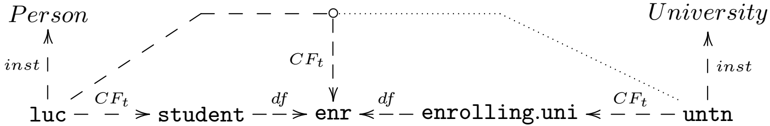
  i.e. x can be defined by y or just 'imported' by it;
- ▷ $\mathsf{df}(x, y)$: "(relational) *concept* x is defined by *relation* y";

  specialization of DF linking a unary property to the relation on the basis of which it is defined following schema (S);
- ▷ $\mathsf{CF}(x_1, \ldots, x_n, y, t)$: "at time t, individuals $x_1, \ldots, x_n$ are classified by *concept/relation* y"

  ($n = 1$ for concepts, $n > 1$ for relations)

Second approach: roles

- 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):



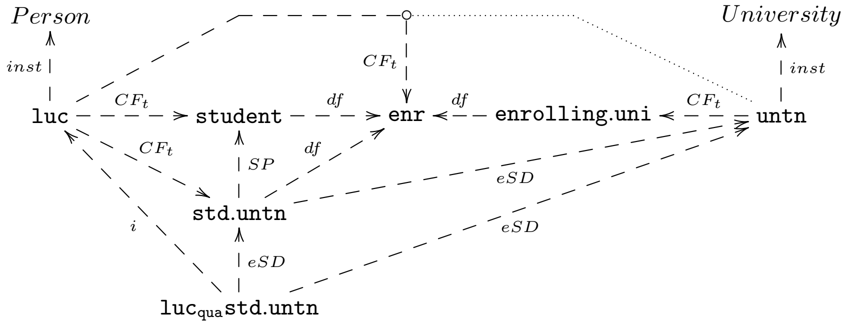
Second approach: qua-individuals (1)

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 in 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)



The counting problem

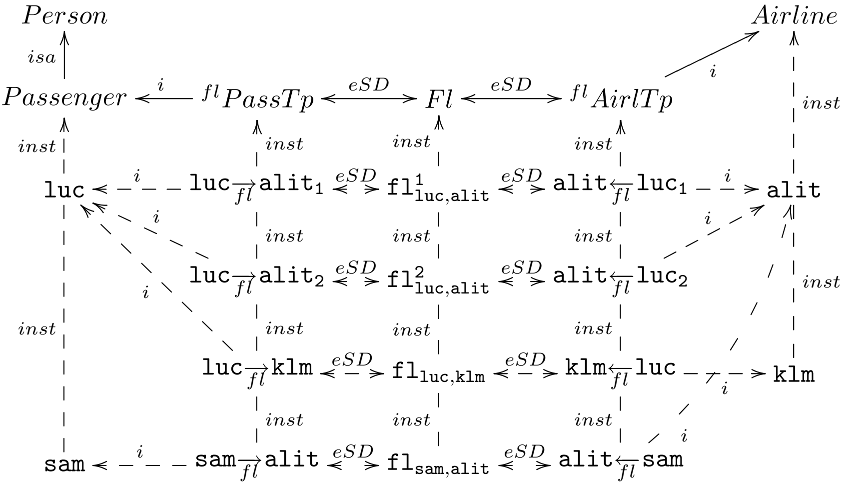
- ▷ Originally formulated by A. Gupta in 1980:
  - – Alitalia served one million passenger in 2004
  - – Every passenger is a person
  - – Ergo, Alitalia served one million persons in 2004.
- ▷ If a given person flew several times Alitalia in 2004, the conclusion is false.
- ▷ Therefore, to count passenger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

Hypothesis. Passenger is based on the 'flies' relation (Fl):

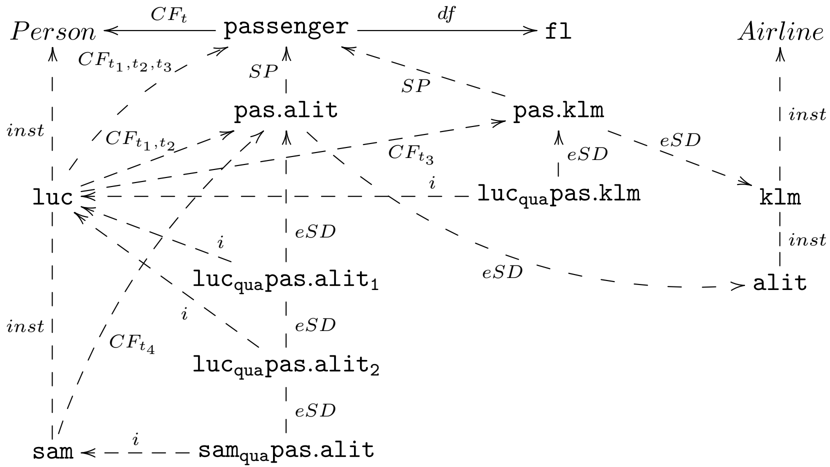
$$Fl(x, y) \rightarrow (Person(x) \wedge Airline(y))$$

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

The counting problem: first approach



The counting problem: second approach



Temporal aspects

▷ Both approaches assume two different entities ($\texttt{luc}_{\overrightarrow{fl}}\texttt{alit}_1$, $\texttt{luc}_{\overrightarrow{fl}}\texttt{alit}_2$ and $\texttt{luc}_{\texttt{qua}}\texttt{pas.alit}_1, \texttt{luc}_{\texttt{qua}}\texttt{pas.alit}_2$) 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:

$$\texttt{luc}_{\overrightarrow{fl}}\texttt{alit}_1, \texttt{luc}_{\texttt{qua}}\texttt{pas.alit}_1 \leadsto Fl(\texttt{luc}, \texttt{alit}, \texttt{t}_1)$$
$$\texttt{luc}_{\overrightarrow{fl}}\texttt{alit}_2, \texttt{luc}_{\texttt{qua}}\texttt{pas.alit}_2 \leadsto Fl(\texttt{luc}, \texttt{alit}, \texttt{t}_2)$$

▷ Qua-entities are in time and differ by their temporal extension:

$$ext_T(\texttt{t}_1, \texttt{luc}_{\overrightarrow{fl}}\texttt{alit}_1) \wedge ext_T(\texttt{t}_2, \texttt{luc}_{\overrightarrow{fl}}\texttt{alit}_2)$$
$$ext_T(\texttt{t}_1, \texttt{luc}_{\texttt{qua}}\texttt{pas.alit}_1) \wedge ext_T(\texttt{t}_2, \texttt{luc}_{\texttt{qua}}\texttt{pas.alit}_2)$$

Relational tropes vs. qua-individuals

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

Both inhere in `luc` and depend on `untn`, but:

▷ $\texttt{luc}_{\overrightarrow{enr}}\texttt{untn}$ represents the 'complex' of all the individual properties that `luc` has by virtue of playing the role "being a student of `untn`"

while

▷ $\texttt{luc}_{\texttt{qua}}\texttt{std.untn}$ is the 'amalgam' of `luc` and all the individual properties he has by virtue of playing the role "being a student of `untn`".

Participation

Let's suppose that `luc` *participates* in 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 in the meeting in a specific way coded by an additional argument (the trope):

  $$\mathsf{PC}(\texttt{luc}, \texttt{meet}, \texttt{luc}_{\overrightarrow{enr}}\texttt{untn})$$

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

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

Conflicting properties

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

Similarly to the participation case:

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

  $$Good(\texttt{luc}, \texttt{luc}_{\overrightarrow{enr}}\texttt{untn}) \wedge Bad(\texttt{luc}, \texttt{luc}_{\overrightarrow{enr}}\texttt{unpd})$$

  (*problem*: which properties/relations need to be qualified?)

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

  $$Good(\texttt{luc}_{\texttt{qua}}\texttt{std.untn}) \wedge Bad(\texttt{luc}_{\texttt{qua}}\texttt{std.unipd})$$

Conclusions

- ▷ The two approaches solve classical problems linked to roles, in addition
  - the first approach harmonizes the anti-rigid view and the rigid types of "adjunct entities" view;
  - the second approach introduces the social dimension and considers 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).