The Counting Problem in the Light of Role Kinds

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Abstract

Starting from a general characterization of roles, we focus on the ways in which roles are specified, we examine the formal constraints on their definitions, and propose definitional schemas motivating different kinds of roles. This classification, in addition to clarify the notion of role itself, helps us to reconsider the two standard solutions that have been proposed for the famous counting problem, and to suggest that a third mixed approach may be considered.

Commonsense allows us to answer the following questions:

1 *How many Alitalia passengers were carried on yesterday's AZ7342 flight?*

2 *How many passengers did Alitalia transport in 2009?*

However, as often happens in commonsense reasoning, a deep ontological analysis is necessary to make explicit what knowledge we use to provide these answers. To count passengers, in sentence (1) it is enough to count persons, the 'players' of the passenger role, while in the case of sentence (2), persons are not enough: the same person can fly several times with the same airline, and even take the same flight in different days. This is the well known *counting problem* (Gupta 1980). The two main solutions in the literature both introduce, in addition to persons, other kinds of entities. The classical solution (see (Barker 2010) for a recent elaboration) introduces and counts *events* (the transportation events in our example), while recent approaches to roles introduce and count entities that *inhere in*, i.e. that are existentially specifically dependent on, but different from, their players, like *qua-entities* (Masolo et al. 2004), *role-holders* (Mizoguchi et al. 2007), or (sums of) *relational tropes* (Guizzardi 2005). We will call these *inherent entities*, and refer to specific instances using the form 'player-*as*-role', e.g. John-as-passenger (of a given flight in a given day).[1]

The approaches based on events allow a uniform solution to the counting problem appearing both in sentences clearly involving roles like (2) and in sentences like "*4000 ships passed through the lock (last year)*", where no role is lexicalized. On the other hand, the approaches based on inherent entities claim that events cannot solve some versions of the counting problem. For example, the multiple participation of a person to a single meeting, that is, in different roles, e.g. as president of a country and president of a company, can lead a person to have multiple rights of vote.

In the following, we will explore a less monolithic solution that, depending on the kinds of roles involved in the counting problem, relies on events or inherent entities. In our opinion, this view can contribute both to mitigate the contrast between the main approaches and to better understand the notion of role. But let us first see some formal aspects of roles, especially those related to inherent entities.

General characterization of roles

General assumptions

Relational roles Roughly speaking, we assume that a role is a *property*, in the sense that different entities can play the same role, *defined by a specification*. For our purposes, *relational roles* — roles defined in terms of a (primitive or complex) n-ary ($n \geq 2$) relation called *founding relation* — are enough.[2] An entity a *plays* the role P if and only if a *satisfies* (all the conditions in) the specification of P.

Formally, by adopting FOL, we represent (i) properties and relations by means of *predicates*, (ii) specifications by means of *syntactic definitions*,[3] and (iii) the 'plays' relation by means of *instantiation*. The general schema for the specifications of relational roles is reported in (d1) where R is the founding relation. For instance, the specification of $\mathsf{Passenger}$ in (d2) is founded on Flies (defined on persons, airlines, flight numbers, and days) and the specification of Child in (d3) on $\mathsf{MotherOf}$ (defined between persons).[4]

d1 $\mathsf{P}(x) \triangleq \exists y_1, \ldots, y_n(\mathsf{R}(x, y_1, \ldots, y_n))$

d2 $\mathsf{Passenger}(x) \triangleq \exists yzv(\mathsf{Flies}(x, y, z, v))$

d3 $\mathsf{Child}(x) \triangleq \exists y(\mathsf{MotherOf}(y, x))$

[1] The subtle differences between inherent-entity approaches (Masolo et al. 2005) are not relevant to the following discussion.

[2] Relational roles are then *definitionally dependent* properties (Fine 1995). We claim neither that the previous characterization *defines* the notion of relational role, nor that all roles are relational. These are open research topics.

[3] We will use the symbol $\triangleq$ to introduce purely syntactic abbreviations. Defined predicates do not belong to the logical vocabulary, they are syntactic sugar with no logical relevance.

[4] For the sake of conciseness, when not necessary, we will not explicitly give *argument restriction* axioms like $\mathsf{Flies}(x, y, z, v) \rightarrow \mathsf{Person}(x) \wedge \mathsf{Airline}(y) \wedge \mathsf{FlightNum}(z) \wedge \mathsf{Day}(v)$.

Anti-ridigity Usually roles are considered as *non essential* or, more specifically, *anti-rigid* (Guarino and Welty 2009) properties of players. Intuitively, it would be possible for the player to exist without being in this role. We adopt anti-rigidity (that, in particular, rules out Child in (d3)) although we will not formally account for this constraint to avoid the subtleties of the notions of *modality* and *possible worlds*. We will discuss a weaker temporal version: at some times, the player exists without playing the role.

Contexts Most approaches to roles consider them as (at least partially) determined by *contexts*. Some works assume contexts without further specifications (Loebe 2007; Searle 1995), other works refer to patterns of relationships (Guarino 1992; Sowa 2000), descriptions (Masolo et al. 2004), modalities of participation to events (Davis and Barrett 2002; Fan et al. 2001), sets of rules that constrain the behavior of players (e.g. in the multi-agent community), or all of these plus objects and events (Mizoguchi et al. 2007).

Here contexts are assimilated to the specifications of roles. We think that, in the case of relational roles, this assumption is quite general. In any case, it does not rule out the critical examples of roles we are interested in.

The structure of specifications

Saturation Roles, such as Passenger in (d2), can be specialized by assuming a more specific founding relation, e.g. 'supersonically flying' in (d4), by restricting one or more arguments of the founding relation (d5), or by instantiating (with a constant) one or more existentially quantified variables (d6)-(d7). Following (Masolo et al. 2004), we will call *saturation* the later case of specialization, e.g. Passenger_alitalia *saturates* Passenger, by instantiating the second argument of Flies with alitalia. Given a $n+1$-ary founding relation, the *completely unsaturated role* with n existential quantifiers (e.g. Passenger in (d2)), can be *completely saturated* by instantiating all the n existentially quantified variables with constants (d7). The completely saturated roles are the most specific roles definable on the basis of a given founding relation.

d4 $\mathsf{Passenger_{Sup}}(x) \triangleq \exists yzv(\mathsf{Flies_{Sup}}(x,y,z,v))$

d5 $\mathsf{Passenger_{It}}(x) \triangleq \exists yzv(\mathsf{Flies}(x,y,z,v) \wedge \mathsf{Italian}(y))$

d6 $\mathsf{Passenger\_alitalia}(x) \triangleq \exists zv(\mathsf{Flies}(x,\mathsf{alitalia},z,v))$

d7 $\mathsf{Passenger\_alitalia\_az7342\_02oct10}(x) \triangleq \mathsf{Flies}(x,\mathsf{alitalia},\mathsf{az7342},\mathsf{02oct10})$

All the previous cases of specialization imply subsumption, therefore the differences among them do not reduce to purely *extensional* considerations but rely on the *way* roles are defined and specialized. In particular, the roles that saturate a given role are all based on the same founding relation, i.e. their specifications are conceptually very close.

Completely saturated roles are central for the counting problem. We have seen that an entity plays a relational role because it satisfies a given (relational) specification, i.e. there exists a *pattern of relationships* between the player and additional (external) entities. It is *in virtue of* the existence of this pattern (and of the additional entities) that an entity plays the role. But, given a founding relation, these patterns must involve specific (tuples of) entities. For example, it is because, say, gino is linked by the relation Flies to alitalia, az7342, and 02oct10 that he plays the role of Passenger_alitalia_az7342_02oct10. However, and this is the interesting point, in virtue of the same pattern, gino also plays the roles of Passenger_alitalia and Passenger. This means that it is not possible to play a *non*-completely saturated role without playing a completely saturated one.[5] This is one of the main motivations underlying the assumption, shared by most of the approaches that admit inherent entities, that inherent entities exist only in relation to completely saturated roles: only gino-as-passenger-of-the-02oct10-alitalia-flight-AZ7342, and not gino-as-passenger-of-alitalia, exists. We will adopt this assumption here.

A last point regards the relationship between saturation and the (in)dependence of existentially quantified variables. For example, let us consider (d2) and assume that some axioms ensure that the flight number univocally determines the airline. In this case, by saturating the flight number and the day arguments (d8), the role becomes completely saturated. In these cases we consider the two roles, e.g. Passenger_az7342_02oct10 in (d8) and Passenger_alitalia_az7342_02oct10 in (d7), as identical.

d8 $\mathsf{Passenger\_az7342\_02oct10}(x) \triangleq \exists y(\mathsf{Flies}(x,y,\mathsf{az7342},\mathsf{02oct10}))$

Complex specifications Until now we considered the founding relation as an atomic formula but, in general, specifications can be complex formulas. Here we focus on formulas that are reducible to prenex disjunctive normal forms (PDNFs) with only existential quantifiers and positive literals. This could seem quite limitative but these formulas are enough for our purposes while maintaining the framework simple. Even in this simple framework, one needs to pay attention to the interaction between saturation and the existence of inherent entities. Let us consider a simple example. According to (d10), a *registered (italian) elector* is an (italian) citizen registered on the electors' list of an italian town. (d10) uses the role Citizen_it, a straight saturation of Citizen defined in (d9). According to (d11), rewritten in PDNF in (d12) (assuming that all the relations in (d12) are primitive), a person can be an (italian) elector for two reasons: (i) he is a registered citizen — in which case he can vote for himself and abandons the possibility of delegating his vote;[6] or (ii) he has been delegated by another citizen — in which case he can vote for somebody else even without being an italian citizen. Notice that (i) and (ii) are not incompatible (the $\vee$ in

[5] In an ontological perspective, the same idea can be stated in terms of *truthmakers* (Armstrong 2004; Beebee and Dodd 2005). Roughly speaking, a truthmaker for a proposition is an entity existing in reality such that, necessarily, if it exists the proposition is true. The nature of truthmakers is highly debated in philosophy, but the main approaches reduce them to *states of affairs* or *tropes* (see (Armstrong 2004) for a discussion). For example, the proposition that the rose is red is made true by the *rose's being red* (the state of affairs or trope), in other words, it is because the *rose's being red* exists that the proposition is true.

[6] We assume that $\mathsf{Delegates}(x,y) \rightarrow x \neq y \wedge \neg\mathsf{RegElector}(x)$.

(d12) is not exclusive): somebody could be both a registered elector and a delegatee and the same person could then have the right to express two votes (double right of vote). Thus counting electors cannot be reduced to counting persons.

d9 $\mathsf{Citizen}(x) \triangleq \exists z(\mathsf{HasPassCountry}(x, z))$

d10 $\mathsf{RegElector\_it}(x) \triangleq \mathsf{Citizen\_it}(x) \wedge \exists y(\mathsf{RegOnTown}(x, y) \wedge \mathsf{In}(y, \mathsf{it}))$

d11 $\mathsf{Elector\_it}(x) \triangleq \mathsf{RegElector\_it}(x) \vee \exists y(\mathsf{Delegates}(y, x) \wedge \mathsf{Citizen\_it}(y))$

d12 $\mathsf{Elector\_it}(x) \triangleq \exists y((\mathsf{RegOnTown}(x, y) \wedge \mathsf{In}(y, \mathsf{it}) \wedge \mathsf{HasPassCountry}(x, \mathsf{it})) \vee (\mathsf{Delegates}(y, x) \wedge \mathsf{HasPassCountry}(y, \mathsf{it})))$

One can then try to solve this counting problem by introducing inherent entities[7] that however, following the assumption of the previous section, exist in relation to completely saturated roles. (d12) contains only one existentially quantified variable, y, therefore Elector_it can be completely saturated by instantiating y with a town (to which the elector is registered), e.g. Rome, or a person (the delegator), e.g. Luca. For a person, say Gino, that is both a citizen registered on Rome's elector list and a delegatee of Luca (he has the right to vote for both himself and Luca), Elector_it_rome is related to the existence of the inherent entity Gino-as-italian-citizen-registered-on-Rome's-list, while Elector_it_luca is related to the existence of Gino-as-italian-elector-delegated-by-Luca. Two different entities exist and the counting problem is solved.[8] Note that this is very similar to the case of the same person that is a passenger of two different airlines (in two different flights and days), the only difference is that in the case of Elector_it we need to check different conditions for registered persons and delegated persons, while in the case of Passenger we consider only the Flies relation. This can be seen as an evidence that Elector_it is not *one* role because it can be played in two different (and independent) ways. It is a sort of 'super-role' that offers a unitary view on the roles defined by its disjuncts. This is still more prominent in the case of disjuncts with a different number of variables because one disjunct will be saturated before the others. In the remainder we will then focus on specifications with only one disjunct in their PDNFs.

Intensionality (d13) defines passengers as persons that participate in transportation events (where PC, the participation relation, Person and Transportation are primitive). (d2) and (d13) *explicitly* refer to different primitive notions: (d2) is based on the Flies relation among persons, airlines, flight numbers, and days but does not refer to events, while (d13) is based on the PC relation between persons and events but does not refer to airlines, flight numbers, or days.

d13 $\mathsf{Passenger}'(x) \triangleq \exists y(\mathsf{PC}(x, y) \wedge \mathsf{Person}(x) \wedge \mathsf{Transportation}(y))$

In absence of links between PC (and Transportation) and Flies, Passenger and Passenger′ are clearly two distinct roles. Things become less obvious by assuming axioms stating that (i) transportation events are managed by a unique airline, have a flight number, and take place on a specific day; and (ii) that when a Flies relation holds, a transportation event occurs. By accepting (i) and (ii), the two different formulas (d2) and (d13) become logically equivalent. Is this enough to conclude that Passenger and Passenger′ are identical? The answer is very difficult and partially relies on the identity criteria assumed for properties, a highly debated topic in philosophy (see (Armstrong 1989) for an introduction). Here we want just to point out a few arguments in favor of an *intensional* (as opposed to *extensional*) point of view on roles. First of all, it seems that the two roles have a different behavior with respect to the saturation mechanism. By instantiating the variable y in (d13) with a specific transportation event, we obtain a completely saturated role because, accepting (i), a transportation event univocally determines the airline, the flight number, and the day. On the other hand, Passenger can be *partially* saturated in different ways, with an airline, a flight number, or a day. More importantly, to check if a person is a passenger, according to the chosen definition, we focus on different patterns of relationships: in the case of Passenger we need to look for Flies patterns, while in the case of Passenger′ for PC patterns. Therefore, assuming that roles are similar to *concepts* in Peirce's semiotic triangle, characterized by *rules* that make it possible to individuate their *referents*, Passenger and Passenger′ happen to be different. In an ontological perspective, this situation is similar to the one analyzed by Elliot Sober (Sober 1982) to show that "logically equivalent predicates may pick out different properties". Sober argues that the property of 'being a closed straight-sided figure having three angles' (being triangular) and that of 'being a closed straight-sided figure having three sides' (being trilateral) are necessarily co-extensive but different because they have different *causal efficacy* (causal power). This argument seems valid also in our framework. For this reason, at this stage, we prefer to assume that Passenger and Passenger′ are distinct.[9]

Roles and time The anti-rigidity of roles is most often interpreted as involving a temporal modality. (Steimann 2000) individuates several *dynamic* characteristics of roles, e.g. an entity *can* change role, it *can* play several roles simultaneously, and the sequence in which roles may be acquired and relinquished can be subject to restrictions. *When* an entity satisfies a specification, i.e., *when* the pattern of relationships in the specification holds, must be made explicit. In FOL, the time at which the role is played is usually represented by adding a temporal argument to the role, so that the schema (d1) is replaced with (d14), where t is a time:

d14 $\mathsf{P}(x, t) \triangleq \exists y_1 ... y_n(\mathsf{R}(x, t, y_1, ..., y_n))$

[7]Events do not help in this case, we are counting the 'rights to vote' not the voting events (see the next section, footnote 14, for additional details on this point).

[8]If the $\vee$ in (d12) is exclusive then only one of the condition could be satisfied by a specific player, and therefore only one inherent entity can exist.

[9]If 'being triangular' and 'being trilateral' are different properties, the truthmakers (states of affairs or tropes) of propositions involving them are different but existentially dependent.

Summing up

We focus here on anti-rigid relational roles explicitly defined by means of a specification based on a founding relation. As a consequence, some intensional aspects of roles can be addressed by taking into account the way they are defined, i.e., the structure of their specifications. In particular, we introduced saturation between roles, that, in addition to extensional subsumption, requires the relata to be defined on the basis of the same founding relation. (Strict) roles are defined by formulas in PDNF with a single disjunct and such that there are only existential quantifiers and only positive literals. This constraint solves some problems linked to the saturation of disjunctive roles, and allows to associate the existence of inherent entities to the playing of completely saturated roles. 'Super-roles', i.e. disjunctions of strict roles, can introduce a unity criterion among roles but the saturation mechanism does not directly apply to them.

We will now see that this framework is not as restrictive as it may seem. Some useful distinctions between roles can be introduced and some challenging versions of the counting problem can be represented and solved.

Different kinds of roles

There are essentially two kinds of roles. The first, that we will call *participation roles*, of which $\mathsf{Passenger}'$ (d13) is an example, is especially examined in the community of linguists and philosophers of language. The second, that we will call *non-participation roles*, of which Citizen (d9) is an example, is focused on by researchers studying deontic aspects of organizations and multi-agent systems. In the AI community at large, both types of roles are considered, but the difference between them has not been pointed out much.

Participation roles

The very idea of counting events to count passengers stems from the fact that many roles can be considered as involving the participation of the player in an event simultaneous with the playing. In the passenger case, these are, for instance, events of transportation of the humans playing the passenger role. This of course presupposes an ontology in which there are events, as in the $\mathsf{Passenger}'$ specification (d13) and not in that of Passenger (d2). Participation usually is temporalized, so the time of role playing is relevant; it is by definition limited to the time of the event, but could be shorter. The basic schema (d15) is thus adapted from (d14) and uses the participation relation PC, assuming (a1).

d15 $\mathsf{P}(x,t) \triangleq \exists e(\mathsf{PC}(x,e,t))$

a1 $\mathsf{PC}(x,e,t) \rightarrow (\mathsf{Exists}(x,t) \wedge \mathsf{Exists}(e,t))$[10]

This would make only an extremely generic definition of just one (unsaturated) role, 'event-participant'. More useful are the sub-kinds of participation roles that can be distinguished.

[10] Exists individuates the times at which an entity exists, is present, is alive. It is different from the existential quantifier that just says that the entity is in the domain of quantification.

Thematic roles Thematic roles are still very generic roles, introduced to analyze linguistic phenomena involving the argument structure of verbs at the syntax-semantics interface. Building on the neo-Davidsonian approach (Parsons 1990), each role is defined on the basis of one sub-relation of the participation relation corresponding to a mode of participation (e.g., Agent, Theme, Instrument, Goal), following the schema (d16) where Q is the qualification of the mode of participation. For instance, the Agent role can be defined with (d17), where $\mathsf{PC}_{\mathsf{Agent}}(x,e,t)$ could be more classically written $\mathsf{Agent\_of}(x,e,t)$ — or rather $\mathsf{Agent\_of}(x,e)$ as thematic roles are usually fixed during the event time. (d16) specializes (d15) in the same way as $\mathsf{Passenger}_{\mathsf{Sup}}$ (d4) specializes Passenger (d2).

d16 $\mathsf{P}(x,t) \triangleq \exists e(\mathsf{PC}_{\mathsf{Q}}(x,e,t))$

d17 $\mathsf{Agent}(x,t) \triangleq \exists e(\mathsf{PC}_{\mathsf{Agent}}(x,e,t))$

We will assume here that PC_{Q} are primitive relations, so that each $\mathsf{PC}_{\mathsf{Q}}(x,e,t)$ is an atom.

Saturating the event argument yields very specific roles, e.g., $\mathsf{Agent\_of\_first\_Everest\_climb}(x,t)$. Most such saturated roles are deviant in the sense that they have a unique player at all times, and can then hardly be seen as properties. This is because most often a thematic role is played by a same single entity during the whole event, so that fixing the event fixes the players of its thematic roles. Leaving the event unsaturated yields more interesting notions of role, as we'll now see.

Thematic roles in specific types of events Many classical examples of roles, like 'passenger', 'climber', 'teacher' or 'witness', can be conceived as sub-kinds of thematic roles. In such cases, on top of a mode of participation, the role definition specifies a type of event, and possibly additional restrictions on the player. For instance, 'passenger' can be defined as the human theme of a transportation event (cf. (d13), in which time and mode of participation were omitted), 'climber' as the agent of a climbing event, and (one sense of) 'teacher' as the agent of a teaching event. The schema now becomes (d18), specializing (d16) in the same way as $\mathsf{Passenger}_{\mathsf{It}}$ (d5) specializes Passenger (d2):

d18 $\mathsf{P}(x,t) \triangleq \exists e(\mathsf{PC}_{\mathsf{Q}}(x,e,t) \wedge \mathsf{C}(x,t) \wedge \mathsf{T}(e))$

where T is a specific type of event, and C is a possible constraint on the player. The type of event can include the specification of other (permanent) participants, as with 'Alitalia passenger', 'math teacher', or 'Everest climber':

d19 $\mathsf{Climber\_everest}(x,t) \triangleq \exists e(\mathsf{PC}_{\mathsf{Agent}}(x,e,t) \wedge \mathsf{Climbing}(e) \wedge \mathsf{PC}_{\mathsf{Goal}}(\mathsf{top\_everest},e))$

It is interesting to note that schema (d18) can be used to define properties such as 'boat-passing-through-the-lock' that are rarely seen as roles, probably because they are of little social relevance and not lexicalized. The fact that the specification of participation roles is based on events explains that it is natural for many scholars to focus on events in the counting problem, and so to handle in a uniform way standard roles like passenger and non-lexicalized roles like 'boat-passing-through-the-lock' (Barker 2010).

Counting thematic roles Counting events indeed is a valid solution for problems involving participation roles (non saturated on the event argument, obviously), provided one assumes that each event of this type has a unique participant filling the relevant thematic role, i.e., where:

a2 $\mathsf{T}(e) \wedge \mathsf{PC_Q}(x,e,t) \wedge \mathsf{PC_Q}(y,e,t) \rightarrow x = y.$

For instance, the transportation events to be counted for passengers are transportation events of a single passenger. Whole flights, and more generally, plural events, are not the relevant events, only some of their singular sub-events need to be picked by the type T. For such types of events, instantiating the event uniquely determines the role player, so that counting events is a valid alternative to counting the inherent entities. This can be seen as a more parsimonious solution, especially in the case of non-lexicalized roles, for which the assumption that players systematically come along with inherent entities appears linguistically unmotivated.

If (a2) is not respected, issues can arise. For instance with non-distributive events involving a plurality. It is classically argued that in "Al and Bill carried a piano upstairs", no piano carrying sub-event by Al or Bill alone exists. This is analyzed in (Landman 2000) as a non-plural event in which the plurality fills the agent thematic role. In this view, the schema (d18) yields a unique player of the relevant piano-carrier role (saturated with the event at hand), the plurality 'Al and Bill'. There arguably though is a sense of 'piano-carrier' for which Al and Bill are each playing the role of piano-carrier. In other words, while acknowledging the non-distributive reading of "Al and Bill carried a piano upstairs", the role of piano-carrier may be seen as distributive. To account for this sense of 'piano-carrier', we need a different schema than (d18), allowing not just for fillers of the relevant thematic role in the event, but also for members of pluralities that are such fillers. However, this way, the counting problem is not solved by counting events, there are not enough events. The only possibility is to count inherent entities.

Non-participation roles

In many cases, the founding relation specifying a role doesn't appear to involve the participation of the player in an event. This is the case of 'citizen' defined in (d9) as the holder of a passport of some country. Similarly, one sense of 'student' or 'teacher' does not focus on a specific studying or teaching event, but rather on the relation 'being enrolled' (in an university) or 'holding a teaching contract' (with a school). Many other social roles, that grant rights and duties, like 'Italian president', only have a non-participational sense. Another example is (biological) 'grandfather', whose specification only remotely, if at all, involves an event in which the player participated, but is in any case not participating at the time of the playing. It can be claimed that 'grandfather' and all kinship biological roles, even 'mother' for which the birth-giving event surely is more prominent, are uniformly conceptualized as based on a stative relation rather than on participation, perhaps considering Child_of as a primitive.[11]

[11] Alternatively, one could call on gene sharing.

Counting non-participation roles One could argue that all these actually *are* participation roles, considering the participation in a certain *state* rather than an event.[12] For instance, the specification of 'citizen' could involve states of passport-holding. However, considering such roles as participation roles would not allow some complex versions of the counting problem to be solved by just counting states. Indeed, what is prominent for what we have called non-participation roles is that the role players can participate in events that are completely unrelated with the specification of the role, and yet do so in their quality of role players. For example, the manager of company-A, a role currently played by Bill, can be invited to participate in a business meeting. The complex version of the counting problem that arises goes this way: if we want to count the managers participating in the business meeting, we cannot count the persons playing a manager role that participate in the meeting, because Bill may participate in the quality of both manager of company-A and manager of company-B (it suffices to imagine a situation in which the managers have a voting right to see that one may want to count the managers, not the persons). But one cannot count either the 'managing' states in which the persons at the meeting participate, because we may find that our rich Bill who already manages company-A and company-B also manages company-C, while the manager of company-C has not been invited to the meeting and is therefore not participating in it. The only way out is thus to consider that non-participation role playing is systematically associated with inherent entities, and that these inherent entities themselves may actually participate in events.

It turns out that this move solves an additional issue. If both the manager role and the meeting-participant role are considered as participation roles, there is no simple way to account for the fact that the manager participates in the meeting while the meeting participant doesn't manage the company, unless some causation fact is introduced. With inherent entities associated to non-participation roles, Bill-as-manager participates in the meeting, while Bill himself, and not Bill-as-meeting-participant, manages the company.

Characterization A general specification schema for non-participation roles can only rely on a negative characterization. Non-participation roles follow the schema (d14), where the PDNF of $\mathsf{R}(x, t, y_1, ..., y_n)$ includes no atom of the type $\mathsf{PC_Q}(x, e, t)$.[13] For instance, assuming Flies is a primitive relation, Passenger defined in (d2) is a non-participation role. If, on the contrary, Flies is itself syntactically defined in terms of the participation to an event at the playing time, Passenger is a participation role.

Historical roles

A third kind of roles could be singled out, *derived* from either a participation role or a non-participation one. The de-

[12] Most ontologies distinguish subcategories of perdurants, occurrents or eventualities. Here, we just assume events and states, and that participation applies to all perdurants.

[13] If $\mathsf{R}(x, t, y_1, ..., y_n)$ includes an atom of the type $\mathsf{PC_Q}(x, e, t')$ where the participation time t' differs from the playing time t, we have a non-participation role. See next section.

rived roles of interest here are specified so that the time of playing of the derived role differs from the time of playing of the original one, following the schema:

d20 $\mathsf{P}(x,t) \triangleq \exists t'(\mathsf{P}'(x,t') \wedge \mathsf{TR}(t',t))$

where P' is some other participation or non-participation role and TR some temporal relation. In the light of the characterization of non-participation roles just given, these derived roles are non-participation roles as soon as TR is not identity; we will see now why we actually want to refine both the schema (d20) and the characterization of non-participation roles based on (d14).

The main case is what can be called *historical roles*, i.e., roles that are played because of the fact that some other role was played in the past. In other words, TR typically is $\prec$.[14]

If we (partially) unfold the specification of the role P' in this schema, we obtain (d21) for historical participation roles and (d22) for historical non-participation roles.

d21 $\mathsf{P}(x,t) \triangleq \exists et'(\mathsf{PC_Q}(x,e,t') \wedge \mathsf{C}(x,t') \wedge \mathsf{T}(e) \wedge t' \prec t)$

d22 $\mathsf{P}(x,t) \triangleq \exists y_1...y_n t'(\mathsf{R}(x,t',y_1,...,y_n) \wedge t' \prec t)$

For example, there clearly is a sense of 'Everest climber' which applies to people who have climbed the Everest at some time in the past, e.g., Tenzing. Similarly, 'witness', 'murderer' or 'victim' are historical participation roles.

The following definition of $\mathsf{Climber\_everest}'$ can be derived from the participation role $\mathsf{Climber\_everest}$ of (d19).

d23 $\mathsf{Climber\_everest}'(x,t) \triangleq \exists et'(\mathsf{PC_{Agent}}(x,e,t') \wedge \mathsf{Climbing}(e) \wedge \mathsf{PC_{Goal}}(\mathsf{top\_everest},e) \wedge t' \prec t)$

The admittance of historical properties to define roles is not as straightforward as it seems. It contradicts the intuition that, to play a role P at t, x must exist at t, i.e., $\mathsf{P}(x,t) \rightarrow \mathsf{Exists}(x,t)$. In the case of (d19), with the assumption on PC made above, this intuition is safe, but this is the strict sense in which Tenzing was playing the participation role $\mathsf{Climber\_everest}$ only during his climb. On the other hand, according to (d23), Tenzing was an Everest climber just after his first Everest climb, days before his death and still is now. In other words, starting from his first ascension, Tenzing plays the role of $\mathsf{Climber\_everest}'$ forever, even when he does not exist anymore. This issue is particularly relevant to the counting problem. We saw above that to solve it, non-participation roles require the use of inherent entities. By definition, these inherent entities are existentially specifically dependent on the role player (Tenzing in the case of the saturated role $\mathsf{Climber\_everest}'\mathsf{\_29may1953climb}$), and they cannot survive their death. So we have the awkward situation in which role playing is associated with inherent entities at some times only.

A quite radical solution is to assume that $\mathsf{Climber\_everest}'$ in (d23) and, more generally, all purely historically defined properties, are not roles but only *façons de parler*. In this view, all roles would need to refer to the actual holding of a property at the playing time, as in (d19) but not in (d23). So the sentence "Tenzing is one of the Everest climbers" would be analyzed as "at some time in the past, Tenzing was playing the role of reaching the Everest summit", i.e. $\exists t(t \prec \mathsf{n} \wedge \mathsf{Climber\_everest}(\mathsf{tenzing},t))$ (where n is the present time), without defining any derived historical role of 'Everest climber'. Therefore, counting all Everest climbers to date amounts to count the persons, live or dead, that have been $\mathsf{Climber\_everest}$ at some time in the past.

This would not exclude that historical properties may be used *in addition*, to constrain some arguments of an actual founding relation, i.e., one that involves a property that actually holds at the time of playing. For example, at t a person is a $\mathsf{CAI\_Climber}$ iff (i) s/he is a member of the Italian Alpine Club, and (ii) s/he has been an actual climber before t (s/he has climbed some mountain before t):

d24 $\mathsf{CAI\_Climber}(x,t) \triangleq \exists yt'(\mathsf{Member\_CAI}(x,t) \wedge t' \prec t \wedge \mathsf{Climber}(x,t'))$

$\exists t'(t' \prec t \wedge \mathsf{Climber}(x,t'))$ constrains the first argument of $\mathsf{Member\_CAI}$, an actual non-participation role grounded on an actual relation holding at t thus guaranteeing the existence of its arguments at t. So players of $\mathsf{CAI\_Climber}$ are associated with some inherent entity at all times they play this role. Similarly, one could hold that in situations in which there is a need to count murderers, either one focusses on the actual murderer role and counts the single murdering events (or equivalently the inherent entities if one assumes these are used for participation roles as well), or one focusses on the conjunction of the historical property with an actual one, and counts, e.g., the murderers under trial.

More generally, we will assume that the PDNF of historical roles include an atom for an actual property of the role player, that is, a property that implies the existence of the role player at the time it exists. At the very least, this property simply is $\mathsf{Exists}(x,t)$.[15] So, we need to replace (d20) with (d25), where P' is a role and AP is an actual property (a3); $\mathsf{Climber\_everest}'$ is then defined by (d26).

d25 $\mathsf{P}(x,t) \triangleq \exists t'(\mathsf{P}'(x,t') \wedge \mathsf{TR}(t',t) \wedge \mathsf{AP}(x,t))$

a3 $\mathsf{AP}(x,t) \rightarrow \mathsf{Exists}(x,t)$

d26 $\mathsf{Climber\_everest}'(x,t) \triangleq \exists et'(\mathsf{PC_{Agent}}(x,e,t') \wedge \mathsf{Climbing}(e) \wedge \mathsf{PC_{Goal}}(\mathsf{top\_everest},e) \wedge t' \prec t \wedge \mathsf{Exists}(x,t))$

This move allows us to solve a counting problem similar to counting managers invited to a meeting, which may also arise with simple historical properties. If one needs to count the Everest climbers participating in a meeting, a person having climbed it twice may need to be counted twice (e.g., for having the right to give two expedition reports). Forcing historical roles to contain an actual property guarantees the existence of inherent entities so that the invitees to such

[14] Another possibility is that the playing holds *before* some event occurs, e.g., defining elector as 'to-be voter'. But such *future roles* are problematic as the future is never certain. For instance, 'elector' cannot be 'to-be voter', as rarely all the people having the right to vote do so. In fact, roles such as 'president-elect' or 'heir apparent' are based either on a past event (thus rather historical roles) or on an actual relation. All of these do though refer to an expected future event, a constraint that could be *added* to a basic role schema.

[15] In this case, and whenever this property is not a relational one, the historical role is a rather weak kind of role, as the players are not involved in any actual relation.

a meeting may be "existing-persons-as-Everest-climbers-of-a-given-climb".

Actually, the same observation has to be made regarding the characterization of non-participation roles. Because of (a1), participation roles following (d15) (or (d18)) are guaranteed to be associated with inherent entities at all times they are played, if one wishes to adopt this general solution. This is not the case for non-participation roles with (d14), while we have no choice, inherent entities must be used to solve the counting problems. So, the final characterization is: non-participation roles $\mathsf{P}(x,t)$ follow the schema (d14), where the PDNF of $\mathsf{R}(x,t,y_1,...,y_n)$ includes no atom of the type $\mathsf{PC_Q}(x,e,t)$ and includes at least an atom of the type $\mathsf{AP}(x,t)$ where AP satisfies (a3).

Conclusion

In this paper we focused on the ways in which roles are specified, examining formal constraints on their definitions and the different definitional schemas motivating the distinction of kinds of roles. We have seen that different kinds of roles fare differently in the counting problem.

This suggests that, in addition to the two standard approaches to solving the counting problem, namely, counting events and counting inherent entities, a third, mixed approach can be considered: counting events for participation roles, and counting inherent entities for non-participation ones. Actually, our study shows that the classical approach of counting events is limited to the participation roles (more precisely to those participation roles that are not based on plural events nor on singular events involving plural arguments), so the only way to preserve it in a larger context is through a mixed approach.

One may consider that uniformly assuming that the playing of a saturated, participation or non-participation, role generates inherent entities yields a more powerful and more elegant theory. On the other hand, one may consider that just relying on events where it makes sense is more parsimonious. Whatever one's inclinations, analyzing the specification of roles enabled us to understand the similarity of lexicalized participation roles like 'passenger' with non-lexicalized ones like 'boat-passing-through-the-lock', and contrast them with non-participation roles like 'citizen'.

We have also examined the more controversial case of historical roles, and shown in which case they are properly defined. This allowed to focus on a further constraint on non-participation roles.

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