The "Qua-Entities" Paradigm versus the Notion of "Role" in NKRL (Narrative Knowledge Representation Language)

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Abstract

We examine in this paper the so-called "counting problem" and the solution (the "qua-entities" paradigm) adopted for dealing with this problem in a Semantic Web context. A number of criticisms have arisen about this paradigm, both from a theoretical (the ontological status of the qua-entities is quite unclear) and from a practical point of view (the systematic adoption of this approach necessarily implies a massive proliferation of individuals). We will show then that the use of the NKRL's notion of role – where the "functional" roles are neatly differentiated from the "semantic" ones, and the two classes of entities make use of different knowledge representation tools – allows us to solve the counting problem in a simple and efficient way. The paper can be seen also as a criticism of the "one and only syndrome" that often affects the knowledge representation milieus and a plea for the use instead of a large variety of modelling tools.

Introduction

The "qua-entities" paradigm – loosely derived from the "qua-Concepts" approach (concepts defined as functions of other concepts) described in a KL-ONE framework (Freeman 1982) – is quite popular today in relation to the theoretical debates about the notion of "role" (Masolo et al. 2004, 2005; Guizzardi 2006; Almeida and Guizzardi 2007; Loebe 2007; Vieu et al. 2008; etc.). See also some recent discussions on this topic held in an "ontolog-forum" context (http://ontolog.cim3.net/forum/ontolog-forum/). This paradigm is often presented, in fact, as the *only possible existing solution* – see, however, Barlatier and Dapoigny (2012: 348-349) – to deal formally with a set of problems that challenge the 'standard' view of roles as anti-rigid and relationally dependent entities introduced, e.g., in Guarino (1992) and Guarino and Welty (2000). In this respect, the "*counting problem*" (Gupta 1980; Wieringa et al. 1995; Masolo et al. 2004, 2005, 2011; Guizzardi 2005, 2006; Almeida and Guizzardi 2007; Loebe 2007; Vieu et al. 2008) is considered "… one of the most difficult to solve" (Masolo et al. 2005: 103). And Loebe asserts (2007: 143) that he is not aware of a solution of the counting problem that could concretely work without introducing some sorts of role instances, qua-individuals, or instances of the "role universals *Q*" in his own theory.

Expressed according to its classical "passenger" formulation – see, e.g., (Masolo et al. 2011) for different formulations – the "counting problem" consists of an argument formed of three sentences:

- Air France served about 60 million passengers in 2011.
- Every passenger is a person.
- Ergo, Air France served about 60 million persons in 2011.

As there certainly have been persons who flew Air France more than once in 2011, simply counting the passengers cannot be considered as *universally equivalent* to counting persons that have played the role of Air France's clients in 2011, and the argument is surely flawed. The 'natural' way of getting rid of the counting problem and of determining then the correct number of clients consists – as suggested, among others, in Masolo et al. (2004, 2011), Vieu et al. (2008) – in counting not the passengers but the *carrying situations* of the type "Air France carried a specific person *x* on the flight *y* on day *z*".

The "qua-entities" solution

The difficulty of finding *adequate modelling tools* to deal in a sufficient complete way with time, situations and events (Trame et al. 2013), the practice of systematically dealing with role-like phenomena according to a "*standard concept in a standard ontology*" option (Zarri 2011), and a "*physicalist propensity*" common in general to the Knowledge

Representation milieus that consists in solving complex representation problems simply by multiplying *physical entities* (Bertino et al. 2011: 291-299) have eventually led a number of scholars in the Semantic Web (at large) domain to propose (and accept) a formalization of the "*carrying situations*" above in terms of "qua-entities/qua-individuals".

According to this approach, we must then associate with *ordinary individuals* like LUC_, JOHN_, PETER_ and JANE_ that 'play' a *specific role* (respectively customer_, husband_, passenger_, student_) with respect to *'external' entities* (CHRYSLER_, MARY_, AIR_FRANCE, HARVARD_UNIVERSITY) *additional* "*qua-individuals*" under the form of, e.g., LUC_{qua}chrysler-customer, $JOHN_{qua}$mary-husband, $PETER_{qua}$airfrance-passenger and $JANE_{qua}$harvard-student. These last should contribute to solve difficulties in the "counting problem" style given that they can take now into account the *particular situations* according to which the original individuals are playing a specific role, allowing then us to specify exactly, for example, what the above different *carrying situations* are. In the *standard* interpretation of qua-entities, these new individuals are *instances ("reification") of the particular roles involved* – they are instances of Quality in Guizzardi (2006), Almeida and Guizzardi (2007). In the standard interpretation, the qua-instances inherit then the properties of the corresponding role and, according to the formulation used, e.g., in Vieu et al., (2008), Masolo et al., (2011), they also '*inhere in*' the original 'players', i.e., they are *existentially dependent on, but different from*, the original individuals LUC_, JOHN_, PETER_ and JANE_. Moreover, they are also *existentially dependent* on (possibly a multitude of) other individuals (CHRYSLER_, MARY_, AIR_FRANCE etc.) that characterize the *circumstances* according to which they play a role. "*Role types*" ("*role templates*") as $Person_{qua}$Customer, $Person_{qua}$Husband, $Person_{qua}$Passenger can be found in Genilloud and Wegmann (2000), Almeida and Guizzardi (2007).

Doubts have been raised, both from a theoretical and a practical point of view, about the *general effectiveness* of this sort of solutions. In particular:

- The ontological status of the qua-entities is far from being evident. According to their standard interpretation, see above, qua-individuals are considered as part of *ordinary ontologies* where they appear as *instances of concepts* like customer_, husband_, passenger_, student_ etc. that correspond to "*roles*". Instantiating "roles" is a *particularly controversial kind of ontological operation*. According to a large consensus – see, e.g., Guarino (1992, 2009, etc.), "a role is … an anti-rigid externally dependent unary property" – roles correspond to *provisional properties*. However, the process of "instantiating a property" *is inconsistent with the usual ontological notion of "instantiation"*, which means creating a *new* concrete example (an individual) *I* of an abstract notion represented by concept *C*. In the case of properties, the usual way of conceiving an "*instantiation*" is to state that the *specific property P* is "*instantiated*" when it is possible to identify an (*already existing*) individual *I* that is characterized by this property. This means that JANE_ – created independently from any "property" consideration – *instantiates* the property student_ or harvard_student by introducing some sort of dyadic relationship *that does not correspond, however, to any sort of "subsumption" notion*. In the "qua-individuals" case, the situation is even more complex given that these individuals, as stated above, are also *existentially dependent* on bunches of disjoint entities (CHRYSLER_, MARY_, HARVARD_UNIVERSITY, AIR_FRANCE etc. in the previous examples) that characterize the circumstances according to which they play a specific role. For other problems (Bradley's regress etc.) linked with the notion of "instantiation of a property" see, e.g., Swoyer and Orilia (2011). As we will later NKRL, the Narrative Knowledge Representation Language (Zarri 2009, 2011a), gets rid of any theoretical problem about instantiation of properties by seeing all the concepts in the style of customer_, husband_, passenger_, student_ etc. as *non-sortal concepts* (i.e., deprived of *direct instances*).
- From a practical point of view, the criticism often raised against the qua-entity solution concerns – as noticed also in Masolo et al. (2004, 2005), Loebe (2007), Vieu et al. (2008), etc. – the *not only inelegant but, mainly, actually impracticable proliferation of individuals* that will occur in case of systematic adoption of this approach. It is difficult, in fact, to imagine the practical exploitation of a non-toy system of reasonable dimensions where the users are regularly obliged to create *new individuals for specifying all the possible everyday behaviors of Luc, John, Peter, Jane and all the others*. Moreover, in large, *operational* knowledge-based systems, the *coherent* management of large amounts of *quasi-identical individuals* proves to be particularly difficult. Taking up this approach would be then in strong contradiction with any possible interpretation of the *Occam's razor* or of the *parsimony principle* where this last, according to Vieu et al. (2008: 122), "… is a principle that no-one, philosopher or computer scientist, renounces to".

The NKRL solution

A quick reminder of some NKRL's characteristics

NKRL makes *conceptually and formally explicit* the *substantial heterogeneity* of the notion of "role" by differentiating neatly between "*semantic*" and "*functional*" roles (Zarri 2011a).

Semantic roles take then into account the *static, classificatory aspects* of the notion of "role"; in agreement with the consensus already mentioned, they are seen then as "*properties*" that characterize the behavior of external entities. More precisely, semantic concepts like student_, passenger_ or customer_ represent (direct or indirect) specializations of the *concept* semantic_role, specialization in turn, through the concept qualifier_, of the high-level concept property_ of HClass see, e.g., Fig. 1 of (Zarri 2011a). HClass, the "Hierarchy of Classes", is the *standard* ontology of NKRL, implemented according to modalities very similar to that of the Protégé's frame model (Noy et al. 2000). Examples of NKRL's semantic roles are extended_family_role, with specializations like boyfriend_, spouse_, parent_, child_ (daughter_ and son_), sibling_; professional_role, which subsumes several sub-categories as civil_service_role, industry/manufacturing_role, military_service_role, medical/hospital_role; transitory/generic_role (candidate_, customer_, passenger_, user_, witness_ …), etc. Guarino's pedestrian_ "non-relational role" (Guarino, 1999) could be rightly included in this last category.

Some important properties of NKRL's semantic roles derive from HClass' logical and semantic structure.

HClass "upper level" is partitioned, in fact, between sortal_concept and non_sortal_concept, i.e., between "*(sortal) notions that can be instantiated directly into enumerable specimens (individuals)*", like chair_ (a physical object) and "*(non-sortal) notions that cannot be instantiated directly into specimens*", like gold_ (a "substance"), white_ (a "color") or student_ (a "property", more exactly, as already stated, a "*semantic role*"). The specializations of sortal_concept like chair_, city_ or european_city can then have *direct instances* (CHAIR_27, PARIS_: in NKRL, the instances of concepts, i.e., the "individuals", are denoted conventionally in upper case Roman characters). By contrast, the non_sortal_concept like gold_, white_ or student_ *can admit further specializations*, see red_gold, whitish_ or university_student, but *do not have direct instances*. With respect to the NKRL's analysis of controversial notions like "substances" and "colors", see again Bertino et al. (2001: 296-299) and Zarri (2009: 123-137).

We can now remark that semantic_role and its specific terms, as specializations of property_, pertain to the non_sortal_concept sub-hierarchy of HClass. This implies that semantic roles like student_ or customer_ or employee_ or boyfriend_ *cannot be endowed with direct instances*. In NKRL, we can then state that, *at a specific date*, JOHN_ is a student_ – i.e., the (individual) JOHN_ has provisionally the property of being a student_ (or customer_ or employee_) – but the creation of a possible individual like STUDENT_1 (or JANE_{qua}harvard-student) is *syntactically and semantically forbidden*. This is quite new in the context of the theoretical studies about the notion of role that, as seen in the previous Section, quite unanimously assume that a "role" can be "*instantiated*".

NKRL's functional roles have been introduced to allow a correct formal modelling of the world's "*structured/dynamic knowledge*". This last concerns the representation of those complex information structures – *temporally ordered and formed of logically/semantically coherent streams of dynamic information units* – that are denoted, according to the context, as "*computational narratives*" (Finlayson et al. 2010), "*eChronicles*" (Westermann and Jain, 2006), "*complex events*" (Stojanovic et al., 2009), "*structured temporal entities*" (Pustejovsky et al., 2005), etc. Each information unit included in the stream, *conventionally denoted as "elementary event" and represented as an autonomous entity in NKRL*, consists in the description of a particular, spatio/temporally constrained, action/state/situation/etc. involving a number ≥ 1 of "static" entities like characters, physical (and abstract) 'objects', locations, symbolic labels denoting other actions/states/situations etc., see Zarri (2009) for additional information on this topic.

Within this general "structure/dynamic knowledge" context, NKRL's "*functional roles*" are conceived as *"linking operators" represented by "primitives" instead of "concepts"*. To represent then a simple elementary event like "John gives a book to Mary" we will make use of the three *functional roles* SUBJ(ect), OBJ(ect) and BEN(e)F(iciary) to introduce, respectively, the *individuals* – i.e., instances of standard HClass "*sortal*" concepts like human_being and book_ – JOHN_, BOOK_1 and MARY_ as "*arguments*" of the semantic predicate MOVE. Denoting with L1 the symbolic label that 'reifies' the global (*n*-ary) formalism – and that can be used to link this event with similar ones in the context of complex scenarios – a (simplified, see Table 1 and 2 below for further details) representation in NKRL format of the above elementary event is then: "(L1 MOVE (SUBJ JOHN_) (OBJ BOOK_1) (BENF MARY_)". Modelling a situation like "Jane is a student" will imply in turn the use of the SUBJ(ect) and MODAL(ity) *functional roles* to introduce, respectively, the *individual* JANE_ (an instance) and the "*semantic role*" student_ (a semantic concept) as arguments of the predicate BEHAVE: "(L2 BEHAVE (SUBJ JANE_) (MODAL student_))". In conformity with the *dynamic, time-dependent characteristics of the notion of functional role*, temporal (and local) information will also be added to state, e.g., that the "transfer" of the book is occurring now or that Jane has kept his student status at Harvard during a given time interval – see in this last context, e.g., Zarri (2009: 75-86).

The formalisms labelled above as L1 and L2 – "predicative occurrences" according to the NKRL's jargon – are obtained by instantiating *n*-ary formal structures called "templates". These last represent the nodes of an unconventional type of hierarchical organization corresponding to a sort of "*ontology of events*" that is labelled as HTemp (hierarchy of

templates) – in NKRL, the two ontologies, HClass and HTemp, are complementary and strictly interconnected. Templates – see Table 1 below for a concrete example – supply then the formal, *n*-ary representation of general classes of elementary events like "move a physical object", "be present in a place", "produce a service", "send/receive a message", "make a change of state happen", etc. HTemp, then, can be assimilated to a sort of "catalogue" of basic structured/dynamic entities (more than 150 presently, February 2015), very easy to extend and customize – see again Zarri (2009) in this context.

Eventually, we can conclude this Section by noticing that NKRL is not only a knowledge representation language, but also a *fully working computer science environment*, implemented in standard Java and built up, mainly, thanks to the financial contribution of several European projects. It has been used to implement several concrete *real world applications*, ranging from the conceptual analysis of news stories in the legal and corporate domains to the use of advanced reasoning techniques in AAL (Ambient Assisted Living) and industrial (gas/oil) contexts, the analysis of the causes of terrorism events, the filtering of inappropriate internet contents, etc.

NKRL and the solution of the "counting problem"

To deal with situations in the "qua-entity" and "counting problem" style, NKRL does not require the addition of ad-hoc entities and makes use instead of its *standard tools, including the syntactic/semantic interactions between "functional" and "semantic" roles*. Let us consider the Behave:Role template, an offspring of the HTemp Behave:HumanProperty template (see the upper part of Table 1) that admits specializations like, e.g., Behave:User. Behave:Role requires the use of the non-sortal semantic_role concept (or of its specializations) as filler of the (mandatory) MODAL *functional role*. If, as in the case of the "qua-entities" and "counting problem" examples considered above, the precise identification of the *external entities* characterizing the circumstances according to which the SUBJ(ect) plays a *semantic role* is required, these entities are inserted as fillers of the (non-compulsory) TOPIC *functional role*. The presence of the OBJ(ect) role is obviously forbidden, *(OBJ), in the predicative occurrences derived from this template; the date-1, date-2 "*determiners*" can be used to specify *how long* the SUBJ(ect) stuck to this role, or the beginning, the end of this particular situation, etc. Determiners are used to introduce *further details* about the basic *n*-ary core, "predicate / functional roles / arguments of the predicate" (see Table 1) of the formal representation of a template/elementary event, but are *never strictly necessary* for a meaningful interpretation of this core. The three main classes of NKRL determiners, "*modulators*", "*location attributes"*, and "*temporal determiners (temporal attributes)*", are described in detail in (Zarri 2009: 70-86).

Using the template of Table 1 and its specializations, one or more "predicative occurrences" (instances of a template) of the Behave:Role type can be generated (*only when needed*) without requiring the introduction of additional formal mechanisms and *without inflating the standard ontologies with an extra amount of ad-hoc entities (individuals)*.

Table 1. The Behave:Role template**.**

name: Behave:Role
father: Behave:HumanProperty
position: 1.11
natural language description: 'A Human Being or a Social Body Acts in a Particular Role'

BEHAVE	SUBJ	*var1*: [*var2*]
	*(OBJ)	
	[SOURCE	*var3*: [*var4*]]
	[BENF	*var5*: [*var6*]]
	MODAL	*var7*
	[TOPIC	*var8*]
	[CONTEXT	*var9*]
	[modulators]	

var1 = human_being_or_social_body
var3 = human_being_or_social_body
var5 = human_being_or_social_body
var7 = semantic_role
var8 = pseudo_sortal_concept, sortal_concept
var9 = situation_, symbolic_label
var2, *var4*, *var6* = location_

virt2.c40)	BEHAVE	SUBJ	INDIVIDUAL_PERSON_102: (GP1Z_MAIN_CONTROL_ROOM)
		MODAL	production_activity_leader
		TOPIC	GP1Z_COMPLEX
		{ obs }	
		date-1:	2008-10-16-08:26
		date-2:	

As an example, let us consider the predicative occurrence (i.e., actually, the NKRL representation of an elementary event) shown in the lower part of Table 1. This example concerns a recent NKRL's application dealing with the analysis and management of "storyboard" in the gas/oil industry domain, see Zarri (2001b). The virt2.c40 occurrence relates the condition of INDIVIDUAL_PERSON_102 as (i.e., "qua") production_activity_leader with respect to the GP1Z_COMPLEX, an installation for the separation of LPG into butane and propane. obs(erve) is a "temporal modulator" (Zarri 2009: 71-72), used to state that, at the specific date associated with the date-1 temporal determiner, the situation described in the predicative occurrence surely '*holds*', even when it is impossible (or simply deprived of interest) to try to specify the real extent of the temporal interval where this situation continues to be 'true'. Changing, in Table 4, INDIVIDUAL_PERSON_102 into PETER_ (the *sole* "Peter individual" that would be needed in the context of a given application), the production_activities_leader

semantic role into the semantic role passenger_ and the individual GP1Z_COMPLEX into the AIR_FRANCE individual – and, of course, introducing the correct specific date – will be sufficient to supply all the elements needed to get rid of any counting problem. Note, moreover, that the details of the flight can be introduced by filling the CONTEXT role with an individual like, e.g., AF_9786 – an instance of the (sortal) concept reified_event, specific term of situation_, see Zarri (2009: 137). The details of AF_9786 can be specified, if necessary, in an additional set of occurrences.

We will evoke here a particular case of "counting problem" – see papers like Masolo et al. (2004, 2005, 2011) for example – where, according to the Authors, *even the qua-entity approach is deemed to fail*. According to Masolo et al (2004: 276) in fact, this approach has difficulties "…with any case in which the event type doesn't select the specific role that the participant is playing during the event". In a situation where a former Italian Prime Minister participates in the same meeting both as Prime Minister and as President of its own Mediaset conglomerate, three (*different*) qua-individuals should indeed be created, INDIVIDUAL_281, INDIVIDUAL_281_{qua}Italian-prime-minister, INDIVIDUAL_281_{qua}Mediaset-president (Masolo et al, 2004: 277), to designate, in reality, the same physical person. The conclusion of the Authors is that, in such cases, no *reasonable* solution to the counting problem seems *even to be possible*.

Once again, the (apparent) impossibility of producing a satisfactory formal model for situations of this type is mainly due to the lack of adequate knowledge representation tools. Let us consider Table 2 below. INDIVIDUAL_PERSON_281 denotes the (*unique*) formal representation of the former Italian Prime Minister that is needed in the context of the previous situation – separate occurrences in the style of occurrence virt2.c40 in Table 1 above can specify his different appointments without requiring the creation of new specific qua-individuals. participant_ is a (non sortal) HClass concept, a particular semantic_role pertaining to its transitory/generic_role branch, see above. According to the definition associated with the TOPIC *functional role* in NKRL, the TOPIC filler – in our case, an "expansion" or "structured argument", see Zarri (2009: 68-70) – introduces further 'local' details about the main theme (here, the participation in a meeting) of the corresponding elementary event. In the predicative occurrence ex1.c1 of Table 2, the filler indicates then that INDIVIDUAL_PERSON_281 took part in this meeting, at the same time (COORD(ination)), as italian_prime_minister (a semantic role concept of the civil_service_role type) and as mediaset_president (a semantic role concept of the professional_role type). acting_as is a (non sortal) concept included in the binary_relational_property branch of the relational_property sub-hierarchy of HClass. Other concepts pertaining to the same branch are, e.g., compared_to, exemplified_by, related_to, replacement_for, etc.; an example of multiple_relational_property concept is between_. The "attributive operator", SPECIF(ication), and the "collective operator", COORD(ination), are two of the *four operators that make up the so-called AECS sub-language*, used for the set-up of the *structured arguments (expansions)*; apart from SPECIF(ication) = S and COORD(ination) = C, AECS includes also the disjunctive operator ALTERN(ative) = A and the distributive operator ENUM(eration) = E. The interweaving of the four operators is controlled by the "*precedence rule*", see Zarri (2009: 68-70). According to the characteristics of the situation considered, further details about the general context of the event, MEETING_213, could be directly introduced in the CONTEXT's filler or specified in separate predicative occurrences. The "*location determiners*" (the individual MILAN_ in our case) introduced by the colon, ":", operator, can only be associated with the fillers of the SUBJ(ect), OBJ(ect), SOURCE and BEN(e)F(iciary) "main" functional roles.

Table 2. Participation in the same event according to different functions.

ex1.c1)	BEHAVE	SUBJ	INDIVIDUAL_PERSON_281: (MILAN_)
		MODAL	participant_
		TOPIC	(COORD (SPECIF acting_as italian_prime_minister) (SPECIF acting_as mediaset_president))
		CONTEXT	MEETING_213
		date-1:	2002-10-21
		date-2:	

Behave:Role (1.11)

Conclusion

We have examined in this paper the so-called "counting problem" and the solutions ("qua-entities" paradigm) that have been proposed for this problem in a Semantic Web context. A number of criticisms have arisen about these solutions, both from a theoretical and a practical point of view. We have shown then that the use of the NKRL's notion of role – where the "functional" roles are neatly differentiated from the "semantic" ones, and the two classes of conceptual entities make use of *coordinated but totally different knowledge representation tools* – allows us to solve the counting problem (and the similar ones) in a simple and efficient way.

More in general, the paper can be seen as a criticism about the "*one and only syndrome*" that often affects the knowledge representation (and Semantic Web) milieus and a plea for the use of a variety of modelling tools, where each

of them can supply *the best fitting solution to take into account a specific aspect of complex, real-world situations*. In NKRL, several representation models are used. The standard ontological "binary" model is utilized for the HClass hierarchy and the "semantic roles". An "*n*-ary" model, based on the notion of "functional roles", is used for representing the nodes of the HTemp "ontology of events". Recursive lists of (reified) symbolic labels are used for modelling the so-called "connectivity phenomena" and for representing correctly full narratives, complex events and situations, see Zarri (2009) for the details. Special representations based on the notions of "category" and "perspective" of dating are employed for representing the temporal phenomena; etc.

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