Some features of the part-of relation with respect to verbal predication

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Quelques spécificités de la relation PARTIE-DE dans le cas du verbe

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1 Parthood Relation: an historical point of view

Theories based on relations between parts and wholes are currenty named mereologies (from the Greek $\mu\epsilon\rho o\varsigma$, part). The roots of mereology can be traced back to the early stage of western philosophy, beginning with the Presocratic. Four notions are connected : part versus bit, whole versus unit.

1.1 In classical times

1.1.1 Heraclite (around 544–480 B.C.)

"The bones connected by joints are at once a unitary whole and not a unitary whole" because they are composed of units (bones).

1.1.2 Plato (427–387 B.C.)

The parthood relation is reduced to a spatial or temporal model. "The unit is neither a part nor a whole. The part is a part of a whole and a whole must have all its parts. If it has no parts, it cannot have a beginning or a middle or an end. (Parmenides, *Thaetetus*)

1.1.3 Aristotle (384–322 B.C.)

(See for instance Metaphysics, Physics, Topics, ...)

The part-whole relation is to ontology and metaphysics as fundamental as essential-accident relation, the four different kinds of cause (material – as a constituent (ingredient: the bronze is cause of the statue) –; formal – the form is the account of the essence –, efficient – the source (the man who give the advice, the producer of the product) –; and final – what it is for : as health for the walk).

He includes the genus-species relation inside part-whole relations in both extensional (class inclusion) and intensional (concept inclusion) senses.

He distinguishes between

- *heap or contingent whole* which is nothing but the sum of its parts, so that parts can exist without the whole : Peter + Mary

- *true whole* which is more than the sum of its parts and the parts cannot exist without the whole. the whole is ontologically prior to its parts : words, syllables and letters, all of which are wholes not exhausted by their parts.

1.1.4 Secstus Ampiricus (160–210)

Secstus Ampiricus surveys the issue in Against physicians (I, 335-337): there are three thesis concerning relations between parts and wholes:

Epicurean thesis: the whole differs from its parts

Stoicism thesis: No part can exist independently from the whole and the whole is exactly the collection of its parts

Scepticism thesis: The part is both different of the whole and the same as the whole.

1.1.5 Euclid (325–265)

The first mereology rules are given under the COMMON NOTIONS inside *Elements, Book 1*

1. Things which equal the same thing also equal one another.
2. If equals are added to equals, then the wholes are equal.
3. If equals are subtracted from equals, then the remainders are equal.
4. Things which coincide with one another, equal one another.
5. The whole is greater than the parts.

These common notions refer to magnitudes of the same kind (lines with lines, surfaces with surfaces, angles with angles). They rest on the fundamental opposition between numbers (integers) and magnitudes (reals) inside Greek mathematics[1]. This opposition is lost in work subsequent to the one of Simon Stevin (1548-1620), who unified numbers and magnitudes.

1.1.6 Medieval mereologies

One can find discussions of parts and wholes throughout the medieval philosophical and theological literature[2] based on the commentaries on Aristotle's Categories and On Interpretation by the Roman philosopher Boethius (c. 480-524 A.D.). He revisited the treatments of division and sum and introduced the notion of potential wholes.

[1] A number refers to a collection of unities. For Aristote, *Physics 207b*: (i) there is no infinite which is greater than any magnitude, but there is an infinite which is greater than any number; (ii) a magnitude is divided infinitively, which is not the case for a number.

[2] Abelard (1079,1142), Peter of Spain (XIII° s.), William d'Ockham (∼1285,1347), Duns Scott (∼ 1266, 1308), John Buridan (∼ 1300,∼1360).

principles :

- *definition*

  a **whole** is anything that is composed out of other items or that can be devided into other items.

  Parts are not bits. There is "a good reason" for a thing to be a part of another thing which is a whole.

- *construction*

  Collections: This is the process whereby a plurality is collected (groupified) into a unity.

  there are

  - universal wholes: species versus genus (classification)
  - integral wholes
    - continuous wholes consist of parts sharing a common boundary
    - discrete consist of parts not sharing a common boundary. The parts can be either close to one another (contiguous), or relatively scattered (scattered).
    - successive whole: temporal wholes or events are not continuous in the way that a bronze rod is continuous. Their parts do not share some spatial boundary, they come one after the other in continuous succession (Aquinas)

    Discrete is used when referring to numbers and continuity to magnitude.
  - potential wholes consist of "powers" or "virtues" like human soul. They are not composed out of other items but they are divisible in one respect: the different functions or powers that it performs.

  Divisions: This is the process whereby any sort of unity is resolved into a plurality.

  Division is associated with the problem of atomicity versus non atomicity, with discretion versus density (see for instance calendar systems and direct limits [17]).

1.2 Moderm mereology

Gottfried Leibniz (1646,1716), Brentano (1838,1917), Edmund Husserl (1859,1938), North Allan Whitehead (1861,1947), Bertrand Russell (1872,1970), Jean Nicod (1893–1924), Norbert Wiener (1894,1964) contributed to mereology both in mathematical terms and ontological terms.

But mereology theories are nowadays mostly based on the work of Leśniewski (1886,1939) [25] and his seminal paper (1916).

We propose here to examine Whitehead's mereology in terms of the following relation of extension, denoted K, which is the inverse of the proper part relation [23]:

(i) aKb implies that a is distinct from b.

(ii) Every event extends over other events and is itself part of other events.

(iii) If the parts of b are also parts of a and a and b are distinct, then aKb.

(iv) The relation K is transitive.

(v) If aKc, there are events such as an intermediate b where aKb and bKc.

(vi) If a and b are any two events, there are events such as e where eKa and eKb.

2 Properties

Besides the traditional properties of binary relations inside a family of things ((ir)reflexivity, (a/anti)symmetry, (anti)transitivity (properties I), we can consider the number of links of one thing according to the relation (Properties II) before treating the properties mentioned in the historical section (properties III).

2.1 Properties I: reflexivity, symmetry and transitivity

antireflexivity Thing A is not a part of thing B

asymmetry If thing A is part of thing B, then B is not part of A

transitivity If thing A is part of thing B, and thing B is part of thing C, then A is part of C

Leśniewski 's original formulation of Mereology (1916) had the primitive 'part' relation which is an asymmetric and transitive relation, hence an irreflexive one. This relation is associated with the 'ingredience' relation, which is its reflexive closure. The ingredience relation is a partial order, named usually 'part-of', the 'part' relation is a strict-ordering and usually named "proper-part-of". As noticed by Peter Simons [18], algebraically, it is more convenient to take the ingredience relation as the primitive one. This was not the concern of the ancients and perhaps not the concern of designers.

The minimal requirements for a system to be a mereology [18] are

- Asymmetry of proper part
- Transitivity of proper part
- Weak supplementation principle: any proper part a of b has a supplementation c which is a disjoint (non overlapping) part of b

2.1.1 Some questions around transitivity

- The transitivity property is intuitive as far as the things are exactly of the same nature. For instance, the relation 'extends over' of Whitehead [23] acts only on the events and has exactly the same meaning, each time it is used[3], and so is naturally transitive.

  Due to the ambiguity of 'part', the transitivity is not intuitive in the following cases:

  (1) a. A soldier is a part of a platoon.
  b. A platoon is a part of a battalion.
  c. *A soldier is a part of a battalion.

[3]In fact, for Whitehead [23, p. 61] relations are primitive and "the natural elements are introduced as in their capacity of relata."

(2) a. A handle is part of the door.
b. A door is a part of a house.
c. *A handle is a part of a house.

(3) a. A core is a part of a cell.
b. A cell is a part of a biological organ.
c. *A core is a part of a biological organ.

The intuitive requirement is that parthoods between two levels of the spate share the same kind of contribution from part related to the whole, in particular, the relata have to be of the same nature.

In example (1), a soldier is appointed to a platoon, it is a member of a platoon. The latter is not of the same nature of a Soldier. A platoon is a subset of a battalion, its nature is closer to a battalion than to a soldier.

- Transitivity of part-of has something to do with *granularity*. A thing in the middle of a chain of transitivity is a whole related to only one of its neighbour. Its being a whole is only a question of point of view. Its plays the part of one of the relata.

2.1.2 Some questions around partial order

Associated with partial order are the following properties:

- linearity: it is not linear, due to the weak supplementation
- extremal elements:
  minimal/minimum element(s): atomicity
  maximal/maximum element(s)

  A *mereogical atom* is a thing with no proper part. An atom is the first element of a chain. Nothing is said about atomism. If there is a finite number of things, the mereology is atomistic.

  Whitehead's events mereology is without extremal elements, atomless.
- discretion/density/continuity:

  Any event is divided *ad libitum*. Infinite divisibility allows the construction of things of a different nature of the elements of the sequence as points with respect to segment or instant with respect to duration[4].

  Whitehead's events mereology is dense.

  In linguistics, there is some confusion between *atomicity* and *punctuality*. Schwer [16] has proposed to substitute to the ambiguous term *point*, the term *specious point* for dealing with atomicity. Atomicity is a mereological property, without any comments about the shape or the dimension of the thing it predicates.

[4]Dans sa Physique, Aristote écrit : le temps est continu par l'instant et se divise par l'instant [IV, 11, 220a5]. Mais l'instant n'est pas une partie du temps [IV, 11, 220a19]. L'instant est d'une part division du temps en puissance et d'autre part limite et unité des deux parties du temps [IV, 13, 222a18]. Un instant est à la fois le début d'une partie du temps et la fin d'une autre partie [IV, 13, 222a12]. L'intermédiaire entre deux instants est toujours un temps [VI, 1, 231b10].

2.2 Properties II: cardinalities

Two parts *overlaps* if their have a common part. According to Aristotle, every part of a true whole cannot exist without it. These kinds of properties have been taken into account in Requirement Engineering (Information System area) under the name *integrity constraints*. For instance, to any relation can be associated a 4-uple (a, b, c, d) – its cardinality (the number of allowed links for each relata, depending on their situation) – where $a, c \in \{0, 1\}$ and $b, d \in \{1, N^5\}$. In mathematical terms [6]:

a says whether the relation is required to be total ($a = 1$) or not ($a = 0$),

b says whether the relation is required to be a function ($b = 1$) or not ($b \neq 1$),

c says whether the relation is required to be a surjection ($c = 1$) or not ($c = 0$),

d says whether the relation is required to to be an injection ($d = 1$) or not ($d \neq 1$),.

Temporal dimensions can be added, saying that the link has to be permanent or not, or relating the spanlifes of the relata.

For a mereology theory, we get the following properties:

a=0 allows a thing not to be a part.

a=1 compels every thing to be at least a part of an other thing.

b=1 does not allow overlapping.

b=N allows overlapping.

c=0 allows a thing to be an atom.

c=1 compels every part to have at least a part.

d=1 compels every thing to be an atom [it is composed of a unique part, that entails that the relation is the ingredience one] because of the supplementation principle.

d=N says nothing.

For instance, Whitehead Mereology is a (1,N,1,N)-relation.

For taxonomy, any class is a subclass of an other class, except the root. Cardinalities can take into account exception.

In Requirement Engineering, relations generally do not relate things of the same kinds, hence, properties of type I are not studied. Composition of relations are also rarely studied. In [6], the composition of cardinalities has been studied and it has been shown that if the cardinality of the resulting relation cannot be determined unambiguously, then the proposed modeling is not the best one.

[5] One can add more precisions, with a subset of the integers.

2.3 Properties III: in linguistics or in cognitive science

Part-of relations are classified [1, 24, 7] in six classes according to three criteria. Let us recall that a part has NON-ARBITRARY boundaries, that is parts differ from bits, e.g. the tail is part of a cat, half a tail is not.

- A part is an autonomous unit, i.e. it is SEPARABLE from the whole.
  e.g. the fingers are parts of a hand.
- It has a specific FUNCTION with respect to the whole
  e.g. a wheel is part of a bicycle.
- A part X of Y is HOMEOMEROUS if X is still Y
  e.g. water and a glass of water.

To this, one can add discretude based on a form of identity ascription.

- A part is an INDIVIDUAL if it has boundaries that pre-exist those of the whole.
  e.g. Humans are individual parts.

Type of part-of	Example	Fonct.	Homeo.	Separ.	Indiv.
component/integral-object	handlebars / bike (guidon)/(vélo)	+	−	+	+
feature/integral-object	paying/shopping (payer)/(faire ses achats)	+	−	−	+
member/group	soldier/regiment (soldat)/(régiment)	+	–	+	+
member/class	worker/proletariat (travailleur)/(prolétariat)	–	–	+	+
member/set, collect.	tree/forest (arbre)/(forêt)	–	–	+	?
portion/mass	grain of salt/salt (grain de sel)/(sel) slice of pie/pie (part de tarte)/(tarte)	–	+	+	–
object/substance	ring/ gold (bague)/(or)	–	–	–	–

Table 1: Some types of Part-whole Relation

3 Part-of relation in verbal predication

Part-of relation is omnipresent in the analysis of verbal predication: either temporality or aspectuality – either lexical (telicity property) or morphological (perfectivity property).

We can divide nominal and verbal expressions into two main classes depending on the way in which their denotations (individuals and eventualities) as a whole stand in relation to

any of their parts. Link [12], Krifka [8], Landman [9], Filip [4] used elementary extensional mereologies for the description of plurals and mass nouns or telic predicates.

Mass and indefinite plural noun phrases have the property of DIVISIBILITY: any part [of the same scale] of something which is P is also P. A part of *water* is still *water*; a part of *apples* are *apples* [if a part is a subset of apples, not a piece of an apple]. Count noun phrases like *an/the/one apple, five apples*, and measure phrases, like *a glass of water*, are not divisible. A part of *an apple* is no more *an apple*.

A part of *swimming* is *swimming*, a part of *reaching the summit* is not *reaching the summit*.

3.1 Aspect

3.1.1 Lexical aspect

TELICITY or predicational aspect or inner aspect is derived on the basis of the information provided by a verb and its arguments (subject too). The term was introduced by Garey [5] as "a telic verb expresses an action tending towards a goal – envisaged as realized in a perfective tense, but as contingent in an imperfective tense ... ATELIC verbs are those which do not have to wait for a goal for their realization, but are realized as soon as they begin.

(4) Mary ate soup.

(5) Mary ate an apple.

Two main approaches have been defined for dealing with telicity, depending on what entities are taken into account : predicates or eventualities. Based on the former, Mourelatos [13] observes that telic predicates denote "those situations that can be directly or intrinsically counted". Hence, in this respect telic predicates behave like count nouns (any proper part of a telic predicate is not of the same type as it). Atelic predicates behave like mass nouns: any part (inside the same scale) of an atelic predicate is of the same kind as itself).

Based on the latter, telicity is defined in terms of end points: 'natural end point'. A telic eventuality has a natural endpoint, an atelic eventuality does not. More precisely, a telic eventuality can be reduced to its (final) end or may have a preparatory phase included. An atelic eventuality has no given end. But what is count is only terminal ends.

Using a geometric description (see for instance [19] of their spanlife, a telic predicate is described as a point or a segment with a right bound, an atelic predicate is described as a segment. The mereologic question is: what kind of part is relevant? In linguistics, what is described is only the salience feature. A linguistic (proper) part of a thing[6] concerns only the *middle part*. Inside the cognitive framework, if a temporal thing has a middle, then it has necessarily a beginning, and an end. Hence our claim is that the (proper) part is one of its left part without its final end point. A part of an atelic thing is hence of the same kind as the whole, but this is not the case for telic ones. They are different according to the status of their final point.

That is why we wish to propose a description of telicity in terms of nature of bounds and their relations rather than in terms of part-whole relation.

[6]If this thing is presented as a point, it is asserted to be taken as atomic.

3.1.2 morphological aspect

The different type of external aspect or aspectual viewpoint can be set naturally in part-whole terms: it is PERFECTIVE if it is presented as a whole, IMPERFECTIVE if it is presented as an inner part[7].

(6) He came when I was reading.

(7) Yesterday, I read two books.

Inside a framework of a relational representation of verbal tenses based on intervals (Klein for instance), imperfectivity and perfectivity are described in terms of inclusion of two intervals: the assertion-one and the event-one. The assertion interval contains the event one for describing the perfectivity, it is included in the event one for describing the imperfectivity.

3.2 Pluractionality

The term PLURACTIONALITY [3, 14, 15, 2] is used to refer to manifestations of plurality in the verbal domain, mostly due to inherent verbal number morphology.

- Cusic has proposed that verbal plurality concerns several conceptual levels, namely OCCASIONS, EVENT, PHASES, and has set up a hierarchy without taking any ontological commitment with respect to the levels. Pluralisation is possible at all level, and at any level 'plural' indicates more than one isomorphic bounded unit of that level [2, p.69]

- Languages use different units for talking about state of affairs and saying how they are bound.
  – Every event is composed of at least one phase and every phase belongs to at most one event.
  – Every occasion is composed of at least one event and every event belongs to at most one occasion.

- Our hypotheses are:
  1 – levels differ with respect to their ontological status:

  events are the only elements with ontological status

  occasions are derived elements but can enjoy an independent status at discourse level. They can be constructed using adverbials, e.g. *three times on Mondays.*

  phases are also derived elements, but they never acquire an independent status at discourse level. In particular, they can neither be counted nor measured.

  2 – The hierarchy can be entered only by the event level, that is the middle one.
  Question: Is the part-of relation the relation that is linguistically relevant when moving up and down the hierarchy?
  3 – The part-of relation used in language is not necessarily associated to a whole. Sums are collections of parts that do not correspond to wholes.

[7] Following Smith [19] there is also a NEUTRAL viewpoint, which present the initial point and at least one stage of a situation. The neutral viewpoint acts as a default viewpoint, and is required for aspectually vague sentence. C. Smith claims that in French, the future tense is of the neutral viewpoint type.

- Cusic reorganises his original three levels in two, where the distinction is between
  – occasion and event repetition, viewed as 'repeated' action cases, also termed EVENT EXTERNAL PLURALITY. Event external plurality results from distribution of an action in time—e.g. frequentative and habitual readings—or over participants—e.g. distributive readings of NPs.
  – phase repetition, viewed as a case of 'repetitive' action, also termed EVENT INTERNAL PLURALITY. Event internal plurality is a form of repetition within the boundary of one event. Two main types are identified.
  Decrease: En. *nibble, sparkle*, Fr. *mordiller* (nibble), *sautiller* (hop), *révasser* (muse)
  Increase: Ar. *kassara* (smash), *ḍarraba* (beat up)

- This reorganization means that:
  – events are the main level, from which the other levels are reached.
  – pluralities of events and occasions share properties that set them apart from pluralities of phases.

- We develop the first point in our ontological hypothesis 1.

- As for the second point, notice that the relation between parts and whole relevant for event-external plurality is of the Stoical type. In an internal plurality, the parts do not exist independently of the whole, with the addition of the Epicurean thesis that the whole is different from its parts.

- In sum, for plurality as expressed by pluractional verbs, it is required:
  – multiplication at one level
  – distribution
  – proportion

- Cusic views verbal plurality as a form of distributivity, insofar as the source of the multitude of occurrences of one event type is identified as a plural participant, or temporal and spacial extension, giving rise to a distributive effect. The formulation of his distributive parameter is intended to apply to external plurality, but also to internal plurality through time distribution.

- This position is endorsed by Lasersohn [11] in his formalisation.

- On the contrary, this has been questioned by Tovena [20, 21, 22], who show how to extend distributivity to diminutive event-internal plurality via the notion of fragmentation, independently from any form of distribution in time.

3.2.1 A formalisation of external plurality

- For a given verb V, the meaning of a pluractional form which is a combination of the verb with a pluractional marker (PA) is as in (8), [11, p.256].

  (8) $\text{V-PA(X)} \Leftrightarrow \forall\ e \in X[P(e)]\ \&\ \text{card(X)} \geq n$

- The property of events P differs for internal and external pluractionals.
  – In event external pluractionals each event is of the type denoted by the verb, thus P=V.

– In event internal pluractionals, P is defined case by case in the lexical entries of the verbs and V is the type of the plurality.

- Lasersohn adds a clause requiring non overlap in either time, space or participants, cf. (9) [11, p.256].

  (9) V-PA(X) $\Leftrightarrow \forall$ e e' $\in$ X[P(e)& $\neg$f(e) $\circ$ f(e')] & card(X) $\geq$ n

  It is the identity of function f, as a temporal or spatio-temporal trace function or a thematic role, that determines whether the distributivity is temporal, spatio-temporal or participant based.

- Tovena [20, 22] has claimed that the main purpose of the non-overlap condition is to ensure disjunction, since disjonction warrants boundedness, and units are a basic ingredient in plurality. This work shows that a plurality of phases cannot be arrived at in the same way as a plurality of events, hence (8) covers only the external plurality case.

- This claim can be reformulated as follows:
  – an event external plurality is a collection of countable units that can be counted.
  – an event internal plurality is a collection of countable units that cannot be counted. This collection is a heap whose cardinality cannot be defined.

3.2.2 A formalisation of internal plurality

Linguistic manifestations of the difference between pluralities of events and of phases are the fact that the latter undergo restrictions—with respect to thematic relations and accessibility at discourse level—that are not shared by events and occasions [20, 22].

- Internally plural events require argument identity across phases. In (10), one or two cuts per apple won't do even if there are many apples, hence many cuts in total.

  (10) Luisa ha tagliuzzato le mele
  Louise chopped the apples

- Internal plurality does not predicate plurality at the discourse referent level.
  Pluractional verbs do not make phases accessible, hence they cannot be ordered in time, nor is it possible to check that the intervals they occur in are disjoint. The running time of phases cannot be specified individually and the trace function is defined for events.

  (11) Daniele ha mordicchiato la matita due volte
  Daniele nibbled the pencil two times
  (two events of nibbling, not two little-bitings making up one nibbling)

The properties of diminutive event internal pluractionality are captured by means of two specific operations of semantic decomposition in the characterisation of the singular event.

- First, a decrease internal plural verbal form lexicalises the groupification of the plurality obtained by locally decomposing the event into a sum of phases.

- Second, in this single event,
  – at least one participant is decomposed into parts, and
  – the phases are subevents affecting the parts of the participant demoted to a sum. Cusic's isomprphic phases, as event internal units, are constructed/derived from the cells of a cover.

- The affected argument usually is the direct object (patient) in transitive verbs.
  – Its thematic role is equated to Landman's mass role [10] that holds true of pairs of phases and cells of the cover, instead of a standard thematic role holding true of pairs of events and individuals.
  – The elements resulting from fragmenting do not surface at discourse referent level. Hence, it is possible to fragment what may not be an overt argument of the verb, e.g. the internal object of an intransitive verb, e.g. 'life' in *vivacchiare*, the patient of an impersonal verb, e.g. 'snow' in *neigeoter*, or the process through the manner, i.e. the issue of the 'energy' involved,, e.g. 'work' in *lavoricchiare*.

- Entry for *tagliuzzare*

  (12) $\lambda x \lambda y \lambda e[(\text{TAGLIUZZARE}(e)\ \&\ \text{Ag}(e,y)\ \&\ \text{Pat}(e,x)) \Leftrightarrow$
  $\exists e'(^*\text{TAGLIUZZAREPart}(e')\ \&\ e{=}\uparrow e'\ \&\ ^*\text{Ag}(e',y)\ \&\ {}^{M}\text{Pat}(e',x))]$

- This use of the mass role makes it possible to get at countability, as the cells of the cover are parts (atoms but not individuals) related to the phases via the role. But it does not allow counting, since the affected participant is fragmented locally and the parts are not accessible at discourse referent level. Phases exist as a reflex of the cells of a cover, but the cover is not known and no contextual parameter is involved/provided. The only accessible elements are the variables for the event and for the participants.

The diminutive form may leave unaffected the telicity of the predicate, as in the case of *tagliuzzare*, it may affect it, as in the case of verbs with conative and incassative readings, or it may be non-explicit about it, as in the case of *mangiucchiare*. Conative and incassative readings obtain when the plural role of the affected argument applies to some but not all the cells of the cover, see Tovena [21].

- The affected participant is fragmented via a new grinding operation that does not return all the parts.

  (13) The UNFAITHFUL GRINDER function 'ug' is that function $C \to M$ such that for every $c \in C$, $\text{ug}(c) = \{z \mid z \subset \bigvee\{x \in M \mid xKc\}\ \&\ z \neq \{x\}\}$.

- The affected argument is related to the event by a fragmented role ${}^{F}\text{R}$, defined as an application of a plural role to some of the cells of a cover, but not all of them, whichever cover is taken.

  (14) FRAGMENTED ROLE ${}^{F}\text{R}$
  Let e be an event,
  ${}^{F}\text{R}(e){=}\ a$ iff a is an atomic individual and $\sqcup(\{\text{g(d)}|\text{d} \in \text{AT}(^*\text{R}(e))\}) = \text{ug}(a)$

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