

Structured Discourse Reference to Individuals

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Abstract

The paper argues that discourse reference in natural language involves two equally important components with essentially the same interpretive dynamics, namely reference to *values*, i.e. (non-singleton) sets of individuals, and reference to *structure*, i.e. the correlation / dependency between such sets, which is introduced and incrementally elaborated upon in discourse. To define and investigate structured discourse reference, a new dynamic system couched in classical (many-sorted) type logic is introduced which extends Compositional DRT (Muskens 1996) with *plural* information states, i.e. information states are modeled as *sets* of variable assignments (following van den Berg 1996), which can be represented as *matrices* with assignments (sequences) as rows. A plural info state encodes both *values* (the *columns* of the matrix store sets of objects) and *structure* (each *row* of the matrix encodes a correlation / dependency between the objects stored in it). Given the underlying type logic, compositionality at sub-clausal level follows automatically and standard techniques from Montague semantics (e.g. type shifting) become available. The idea that plural info states are *semantically* necessary is motivated by relative-clause donkey sentences with *multiple singular* anaphors: *mixed reading* (weak & strong) sentences and sentences exemplifying *donkey anaphora to structure*.

1. Multiple Donkey Anaphora

The main goal of this paper is to argue that discourse reference in natural language involves two equally important components with essentially the same interpretive dynamics, namely reference to *values*, i.e. (non-singleton) *sets of individuals*, and reference to *structure*, i.e. the *correlation / dependency* between such sets, which is introduced and incrementally elaborated upon in discourse.

The notion of *structured discourse reference* enables us to give a compositional account of the multiple donkey sentences in (1) and (2) below.

Indefinites introduce a discourse referent (dref) u_1, u_2 etc., represented by a superscript, while pronouns are anaphoric to a dref, represented by a subscript.

1. Every u_1 person who buys a u_2 book on amazon.com and has a u_3 credit card uses it u_3 to pay for it u_2 .
2. Every u_1 boy who bought a u_2 Christmas gift for a u_3 girl in his class asked her u_3 deskmate to wrap it u_2 .

Both sentences contain *multiple* instances of donkey anaphora that are semantically correlated: (1) shows that singular donkey anaphora can refer to (non-singleton) *sets of individuals*, while (2) shows that singular donkey anaphora can refer to a *structured dependency* between such sets. Let us examine them in turn.

Sentence (1) is a *mixed weak & strong* donkey sentence: it asserts that, for *every* book (strong) that any credit-card owner buys on amazon.com, there is *some* credit card (weak) that s/he uses to pay for the book. Note also that the credit card *can vary* from book to book, e.g. I can use my MasterCard to buy set theory books and my Visa to buy detective novels, which means that even the *weak* indefinite a^{u_3} *credit card* can introduce a non-singleton set.

For each buyer, the two sets of objects, i.e. all the purchased books and some of the credit cards, are correlated and the dependency between these sets – left implicit in the restrictor of the quantification – is specified in the nuclear scope: each book is correlated with the credit card that was used to pay for it.

The translation of sentence (1) in classical (static) first-order logic is provided in (3) below.

3. $\forall x(\text{pers}(x) \wedge \exists y(\text{bk}(y) \wedge \text{buy}(x,y)) \wedge \exists z(\text{card}(z) \wedge \text{hv}(x,z))$
 $\rightarrow \forall y'(\text{bk}(y') \wedge \text{buy}(x,y'))$
 $\rightarrow \exists z'(\text{card}(z') \wedge \text{hv}(x,z') \wedge \text{use_to_pay}(x,z',y'))$)

The challenge posed by sentence (1) is to *compositionally* derive its interpretation while allowing for: (i) the fact that the two donkey indefinites in the restrictor of the quantification receive two distinct readings (strong and weak respectively) and (ii) the fact that the value of the weak indefinite a^{u_3} *credit card* covaries with / is dependent on the value of the strong indefinite a^{u_2} *book* although the strong indefinite cannot syntactically scope over the weak one, since both DP's are trapped in their respective conjuncts.

Sentence (2) contains two instances of *strong* donkey anaphora: we are considering *every* Christmas gift and *every* girl. The restrictor introduces a dependency between the set of gifts and the set of girls: each gift is correlated with the girl it was bought for. The nuclear scope of the donkey quantification retrieves not only the two sets of objects, but also the *structure* associated with them, i.e. the dependency between them: each gift was wrapped by the deskmate of the girl that the gift was bought for. Thus, we have here *donkey anaphora to structure* in addition to donkey anaphora to values.

Importantly, the structure associated with the two sets, i.e. the dependency between gifts and girls, is *semantically* encoded and not pragmatically inferred: the correlation between the two sets is not left vague / underspecified and subsequently made precise based on various extra-linguistic factors.

The justification for this observation is provided by the following situation: suppose that John buys two gifts, one for Mary and the other for Helen; moreover, the two girls are deskmates. Intuitively, sentence (2) is true if John asked Mary to wrap Helen's gift and Helen to wrap Mary's gift and it is false if John asked each girl to wrap her own gift. But, if the relation between gifts and girls were vague / underspecified, we would predict that sentence (2) should be true even in the second situation.

2. Plural Compositional DRT (PCDRT)

To give a compositional account of sentences (1) and (2) above, I will introduce a new dynamic system couched in classical (many-sorted) type logic and which extends Compositional DRT (CDRT, Muskens 1996) in two ways: (i) with *plural information states* and (ii) with *selective generalized quantification*. The resulting system is dubbed Plural CDRT (PCDRT).

The main technical innovation relative to CDRT is that, just as in Dynamic Plural Logic (van den Berg 1996),

information states I, J etc. are modeled as *sets* of variable assignments i, j etc.; such *plural* info states can be represented as matrices with assignments (sequences) as rows, as shown in (4) below.

4. Info State I	...	u	u'	...
i_1	...	x_1 (i.e. $u'i_1$)	y_1 (i.e. $u'i_1$)	...
i_2	...	x_2 (i.e. $u'i_2$)	y_2 (i.e. $u'i_2$)	...
i_3	...	x_3 (i.e. $u'i_3$)	y_3 (i.e. $u'i_3$)	...
...

Values: the sets $\{x_1, x_2, x_3, \dots\}$ and $\{y_1, y_2, y_3, \dots\}$. **Structure:** the relation $\langle x_1, y_1 \rangle, \langle x_2, y_2 \rangle, \langle x_3, y_3 \rangle, \dots$.

Plural info states encode discourse reference to both values and structure. The values are the sets of objects that are stored in the *columns* of the matrix, e.g. a dref u for individuals stores a *set* of individuals relative to a plural info state, since u is assigned an individual by each assignment (i.e. row). The structure is *distributively* encoded in the *rows* of the matrix: for each assignment / row in the plural info state, the individual assigned to a dref u by that assignment is structurally correlated with the individual assigned to some other dref u' by the same assignment.

More precisely, we work with a Dynamic Ty2 logic – following Muskens' reformulation of dynamic semantics (Muskens 1996) in Gallin's Ty2 (Gallin 1975). There are three basic types: type t (truth-values), type e (individuals; variables: x, x' etc.) and type s ('variable assignments'; variables: i, j etc.). A suitable set of axioms ensures that the entities of type s behave as variable assignments.

A dref for individuals u is a function of type se from 'assignments' i_s to individuals x_e (the subscripts on terms indicate their type). Intuitively, the individual $u_{se}i_s$ is the individual that the 'assignment' i assigns to the dref u .

Dynamic info states I, J etc. are *plural*: they are *sets* of 'variable assignments', i.e. they are terms of type st . A sentence is interpreted as a Discourse Representation Structure (DRS), i.e. as a relation of type $(st)((st)t)$ between an input info state I_{st} and an output info state J_{st} .

The general form of a DRS is [**new dref's** | **conditions**], which abbreviates the term $\lambda_{I_{st}}.\lambda_{J_{st}}. I[\text{new dref's}]J \wedge \text{conditions}J$, whereby the input info state I differs from the output state J at most with respect to the **new dref's** and all the **conditions** are satisfied relative to the output state J . For example, the DRS $[u, u' | \text{person}\{u\}, \text{book}\{u'\}, \text{buy}\{u, u'\}]$ abbreviates the term $\lambda_{I_{st}}.\lambda_{J_{st}}. I[u, u']J \wedge \text{person}\{u\}J \wedge \text{book}\{u'\}J \wedge \text{buy}\{u, u'\}J$. The actual definition of dref introduction, i.e. random (re)assignment, is: $[u := \lambda_{I_{st}}.\lambda_{J_{st}}. \forall i_s \in I(\exists j_s \in J(i[i]j)) \wedge \forall j_s \in J(\exists i_s \in I(i[i]j))]$.

DRS's of the form [**conditions**] are *tests* and they abbreviate terms of the form $\lambda_{I_{st}}.\lambda_{J_{st}}. I=J \wedge \text{conditions}J$, e.g. $[\text{book}\{u'\}]$ abbreviates the term $\lambda_{I_{st}}.\lambda_{J_{st}}. I=J \wedge \text{book}\{u'\}J$. Conditions are interpreted *distributively* relative to a plural info state, e.g. $\text{buy}\{u_1, u_2\} := \lambda_{I_{st}}. I \neq \emptyset \wedge \forall i_s \in I(\text{buy}(u_1 i, u_2 i))$.

An individual dref u stores a set of individuals with respect to a plural info state I , abbreviated as $uI := \{u_{se}i_s; i_s \in I_{st}\}$, i.e. uI is the image of the set of 'assignments' I under the function u .

Given the underlying type logic, compositionality at sub-clausal level follows automatically and standard techniques from Montague semantics (e.g. type shifting) become available. In more detail, the compositional aspect

of interpretation in an extensional Fregean/Montagovian framework is largely determined by the types for the (extensions of the) 'saturated' expressions, i.e. names and sentences. Abbreviate them as **e** and **t**.

An extensional static logic identifies **e** with e and **t** with t . The denotation of the noun *book* is of type (\mathbf{et}) , i.e. $(\mathbf{et}): \text{book} \rightsquigarrow \lambda x_e. \text{book}_{et}(x)$. The generalized determiner *every* is of type $(\mathbf{et})(\mathbf{et}\mathbf{t})$, i.e. $(\mathbf{et})(\mathbf{et}t)$.

PCDRT assigns the following dynamic types to the 'meta-types' **e** and **t**: **t** abbreviates $(st)((st)t)$ (i.e. a sentence is interpreted as a DRS) and **e** abbreviates se (i.e. a name is interpreted as a dref). The denotation of the noun *book* is still of type (\mathbf{et}) : $\text{book} \rightsquigarrow \lambda v_e. [\text{book}\{v\}]$ (i.e. $\lambda v_e.\lambda I_{st}.\lambda J_{st}. I=J \wedge \text{book}\{v\}J$). The determiner *every* is still of type $(\mathbf{et})(\mathbf{et}\mathbf{t})$: $\text{every}^u \rightsquigarrow \lambda P'_{\mathbf{et}}.\lambda P_{\mathbf{et}}. [\mathbf{every}_u(P'(u), P(u))]$. The general format for the conditions that define *dynamic selective generalized quantification* is given in (5) below.

$$5. \mathbf{det}_u(D_1, D_2) := \lambda_{I_{st}}. I \neq \emptyset \wedge \mathbf{DET}(u[D_1]I, u[(D_1; D_2)I])$$

where D_1 and D_2 are DRS's (of type $\mathbf{t} := (st)((st)t)$) and $u[D_1] := \cup\{uJ: ([u | \mathbf{unique}\{u\}]; D)IJ\}$ and $\mathbf{unique}\{u\} := \lambda_{I_{st}}. I \neq \emptyset \wedge \forall i_s \in I \forall i'_s \in I (i_s = i'_s)$ and **DET** is the corresponding static determiner.

Note that ' \wedge ' is static (classical) conjunction and ' $;$ ' is dynamic conjunction; the latter is interpreted as relation composition, i.e. $D_1; D_2 := \lambda_{I_{st}}.\lambda_{J_{st}}. \exists H_{st}(D_1IH \wedge D_2HJ)$.

3. Multiple Donkey Anaphora in PCDRT

In PCDRT, indefinites non-deterministically introduce both values and structure, i.e. they introduce *structured sets* of individuals. Pronouns are anaphoric to such sets.

The weak / strong donkey ambiguity is attributed to the indefinite articles; this enables us to give a compositional account of the mixed reading (weak & strong) sentence in (1) because we *locally* decide for each indefinite article whether it receives a weak or a strong reading. The two basic meanings have the format in (6).

$$6. \text{weak indef's: } a^{\mathbf{wk}:u} \rightsquigarrow \lambda P'_{\mathbf{et}}. \lambda P_{\mathbf{et}}. [u]; P'(u); P(u)$$

$$\text{strong indef's: } a^{\mathbf{str}:u} \rightsquigarrow \lambda P'_{\mathbf{et}}. \lambda P_{\mathbf{et}}. \mathbf{max}^u(P'(u); P(u))$$

The only difference between a weak and a strong indefinite article is the presence vs. absence of a maximization (**max**) operator. We can therefore think of the singular indefinite article as *underspecified* with respect to the presence / absence of this operator: the decision to introduce it or not is made online depending on both the discourse and utterance context of a particular donkey sentence, much like aspectual coercion or the selection of a particular type for the denotation of an expression are context-driven online processes.

The **max** operator (defined in (7) below) ensures that, after we process a strong indefinite, the output plural info state stores with respect to the dref u the *maximal* set of individuals satisfying both the restrictor dynamic property P' and the nuclear scope dynamic property P . In contrast, a weak indefinite will non-deterministically store *some* set of individuals satisfying its restrictor and nuclear scope.

$$7. \mathbf{max}^u(D) := \lambda_{I_{st}}.\lambda_{J_{st}}. ([u]; D)IJ \wedge \forall K_{st}([u]; D)IK \rightarrow uK \subseteq uJ,$$

where D is a DRS (of type $\mathbf{t} := (st)((st)t)$).

The PCDRT analysis of the *mixed reading* (weak & strong) donkey sentence in (1) above is as follows. The indefinite $a^{\mathbf{str}:u_2}$ *book* in (1) is strong and the indefinite $a^{\mathbf{wk}:u_3}$ *credit card* is weak. By the time we have finished

processing the restrictor of the quantification in (1), we will be in a plural info state that stores: (i) the *maximal set* of purchased books (stored relative to the dref u_2); (ii) *some* non-deterministically introduced *set* of credit cards (stored relative to the dref u_3) and, finally, (iii) *some* non-deterministically introduced *structure* correlating the values of u_2 and u_3 .

The nuclear scope of the quantification in (1) is anaphoric to both values and structure: we test that the non-deterministically introduced value for u_3 and the non-deterministically introduced structure associating u_3 and u_2 satisfy the nuclear scope condition, i.e., for each 'assignment' in the info state, the u_3 -card stored in that 'assignment' is used to pay for the u_2 -book stored in the same 'assignment'. That is, the nuclear scope elaborates on the unspecified dependency between u_3 and u_2 introduced in the restrictor of the quantification – and introducing such a dependency does not require the strong indefinite to syntactically take scope over the weak one.

The PCDRT analysis of sentence (2) is largely parallel to the analysis of sentence (1). By the time we have finished processing the restrictor of the quantification in (2), we will be in a plural info state that stores both values and structure, i.e., for each particular boy, we will have: (i) the *maximal set* of gifts that the boy bought for some girl (stored relative to dref u_2), (ii) the *maximal set* of girls for which the boy bought a gift (stored relative to dref u_3) and (iii) the structure associating the u_2 -values and the u_3 -values, i.e., for each 'assignment' in the plural info state, the u_2 -gift stored in that 'assignment' was bought for the u_3 -girl stored in the same 'assignment'.

When we process the nuclear scope of the quantification in (2), we are anaphoric to both values and structure: we require each 'assignment' in the plural info state to be such that the deskmate of the u_3 -girl in that 'assignment' was asked to wrap the u_2 -gift in the same 'assignment'. Yet again, the nuclear scope of the quantification elaborates on the structured dependency between the two sets of values (gifts and girls) introduced in the restrictor.

The compositionally obtained PCDRT representations for sentences (1) and (2) are provided in (8) and (9) below (*her deskmate* in (2) is analyzed as a Russellian definite description, i.e. as contributing existence and uniqueness).

8. [**every** u_1 , ($\{pers\{u_1\}\}$); **max** u_2 ($\{bk\{u_2\}, buy\{u_1, u_2\}\}$);
 $\{u_3 \mid card\{u_3\}, hv\{u_1, u_3\}\}$,
 $\{use_to_pay\{u_1, u_2, u_3\}\}$]
9. [**every** u_1 , ($\{boy\{u_1\}\}$); **max** u_2 ($\{gift\{u_2\}\}$);
max u_3 ($\{girl\{u_3\}, buy_for\{u_1, u_2, u_3\}\}$),
max u_4 ($\{deskmate\{u_4\}, of\{u_4, u_3\}\}$);
unique u_5 , $\{u_4\}$; $\{ask_to_wrap\{u_1, u_4, u_2\}\}$]

4. Comparison with Other Dynamic Systems

PCDRT differs from previous dynamic systems in three respects. The first difference is conceptual: PCDRT explicitly embodies the idea that reference to *structure* is as important as reference to *value* and that the two should be treated in parallel (see the definition of dref introduction in section 2 above).

The second difference is empirical: the motivation for *plural* information states is provided by *singular* and *intra-sentential* donkey anaphora, in contrast to the

previous literature which relies on *plural* and *cross-sentential* anaphora (see van den Berg 1996, Krifka 1996, and Nouwen 2003 among others).

Importantly, donkey anaphora to structure provides a much stronger argument for the idea that plural info states are *semantically* necessary. To see this, consider anaphora to value first: a pragmatic account is plausible for cases of cross-sentential anaphora (e.g. in *A man came in. He sat down*, the pronoun *he* can be taken to refer to whatever man is pragmatically brought to salience by the use of an indefinite in the first sentence), but less plausible for cases of intra-sentential donkey anaphora (no single donkey is brought to salience in *Every farmer who owns a donkey beats it*).

Similarly, a pragmatic account of anaphora to structure is plausible for cases of cross-sentential anaphora like *Every man saw a woman. They greeted them*. This discourse asserts that every man greeted the woman/women that he saw, i.e. the greeting structure is the same as the seeing structure – but the identity of structure might be a pragmatic addition to semantic values that are *unspecified* for structure (e.g. the second sentence *They greeted them* could be interpreted cumulatively in the sense of Scha 1981). However, a pragmatic approach is much less plausible for cases of intra-sentential donkey anaphora to structure instantiated by sentence (2) above.

Third, PCDRT takes the research program in Muskens (1996) of unifying different semantic frameworks, i.e. Montague semantics and dynamic semantics, one step further: PCDRT unifies in *classical type logic* the static, compositional analysis of generalized quantification in Montague semantics and van den Berg's Dynamic Plural Logic.

Moreover, the underlying classical type logic can be extended in the usual way with additional sorts for eventualities, times and possible worlds, which would enable PCDRT to account for *temporal* and *modal* anaphora and quantification in a way that is *parallel* to the account of individual-level anaphora and quantification (for more discussion, see Stone 1997 and Brasoveanu 2006 among others).

5. References

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