On constructive semantics of natural language

Alexander Dikovsky

1 Introduction

The traditional approach to formal semantics of Natural Language is analytical in the sense that it represents the *hearer's stance*, in order to be uniform with 'Speaker's stance'. However, to interpret the discourse, the hearer resolves complex extralinguistic problems, such as scene analysis, events sequencing, propositional attitude analysis, co-reference resolution, etc. using complex extralinguistic ontological knowledge. So from this stance it is very difficult, if possible, to separate the linguistic faculty in the strict sense from the rational agent's faculties. This partly explains why the traditional formal NL semantics are defined in terms of truth in models. Even the underspecified NL semantics (cf. [2, 3, 15]) only postpone the truth analysis by separating non-compositional noun phrase scoping analysis and predication-argument analysis. On the contrary, the *Speaker's stance* is strictly linguistic. It consists in introducing objects, stating facts about them and relating them to the objects previously introduced. The speaker's task is to *express*, not to *interpret*. Let us see an example. *Currently, insurers can increase premiums by (levying surcharges if they determine (a driver)*$_{\Downarrow_\mathsf{x}}$ *is more than 50 percent to blame for a collision)*$_{\Downarrow_\mathsf{e}}$. *(Such penalties)*$_{\Downarrow_\mathsf{p}\ (\mathsf{e} \in \mathsf{p})}$ *often cost* $0_{\Uparrow_\mathsf{x}}$ *hundreds of dollars annually for up to six years. (About half of (the 50,000 cases disputed each year)*$_{\Downarrow_\mathsf{c}\ (\mathsf{c} \sim \mathsf{p})}$*)*$_{\Downarrow_{\mathsf{c_h}}\ \mathbf{part}^{\sim}_{0.5}(\mathsf{c_h}, \mathsf{c})}$ *are overturned by the appeals board. (Those drivers)*$_{\Downarrow_\mathsf{d}\ \mathbf{of-concern}(\mathsf{d}, \mathsf{c_h})}$ *are issued refunds.* [The Boston Globe, March 2, 2009].

Here are tagged the constituents describing entities and events related between them within this discourse. Suppose that $\Downarrow_\mathsf{x}$ in *(a driver)*$_{\Downarrow_\mathsf{x}}$ means something like: "a new semantical object x will identify the entity denoted by the selected occurrence of *a driver* in the discourse", that $\Uparrow_\mathsf{x}$ is the object identified by x and that $\mathsf{x} \sim \mathsf{y}$ means that x and y identify the same entity. Then e identifies the act of *levying*, which is a special case of the *penalties* p that cost much to the *drivers* x (elided in the text). Further, c are the *disputed cases*, $\mathsf{c} \sim \mathsf{p}$ states that c identifies the same object as p and $\mathsf{c_h}$ identifies *about half of them..overturned...* Finally, d are the *drivers* concerned with the cases $\mathsf{c_h}$.

From the Speaker's stance these facts and referential relations are *given*. The Speaker, as a linguistic agent, should only express them. At that, "to express" means two tasks: the first being to implement the facts and the relations by sentences, the other being to relate them through co-reference with the entities and the relations introduced in the preceding discourse (i.e. to construct/update the discourse model). Of course, model updates may introduce inconsistencies: a fact $p(a)$ in the model for the preceding discourse will contradict the new fact $\neg p(b)$ if the co-reference $a \sim b$ is also added. But the task of interpretation of the discourse, in particular of checking consistency of the new model with respect to the models of the preceding propositions, is the task of a rational agent which represents a part of Hearer's stance.

This restriction of formal Speaker's stance NL semantics to models' *construction / updates* permits one to significantly simplify both, the basic features of the language of semantical expressions, and the logical means needed for the definition of such semantics. In particular, there is no more need for object variables: all entities and events may be denoted by *constants* (cf. the conventional dynamic logical discourse semantics, such as DRT [8, 14], where the objects are denoted by reference variables because an update consists in finding an object assignment making new facts compatible with the original model). The other implicit simplification is that the models for this semantics are *finite*. Indeed, on the one hand, they contain only the facts and the co-reference relations of concern for the objects "mentioned" in finite discourses and, on the other hand, the Open World Assumption is no more needed when consistency is omitted. We avoid using the term "model" for such possibly inconsistent finite relational structures and use the term *context* instead. By the way, the consistency check becomes a polynomial time procedure. In this way, we arrive at a formal semantics which is *constructive* in the sense that the semantical operator applied to a succeeding expression in the sequence of semantical expressions defining the meaning of a discourse *updates* the finite contexts of the preceding expressions. One may hope that due to the Speaker's stance restrictions this constructive semantics is monotonic. On the other hand, the language of this semantics should possess features permitting us to explain different kinds of determiners, quantifier words, plurality markers, etc. and the semantics should systematically compute new facts, objects and relations between them from these markers. So the new semantics should also be constructive in the logical sense of the term.

Our general goal is to define the constructive Speaker's stance semantics in a completely compositional way and to show that it is monotonic and can be implemented in polynomial time. In the restricted limits of this paper we cannot elaborate upon the dynamic aspect of this semantics so we dwell on its language and its definition in a given context (i.e. on its *static semantics*).

2 Discourse Plans

Semantic expressions of our semantics, called *discourse plans* (DP), have previously been explained in our papers [5, 4]. Below, a discourse is seen as a sequence of DP. The complete syntax of DP is defined together with their static semantics. In this section, we introduce, comment and illustrate their main features.

Predication modulo diatheses. Following the tradition going back at least to Aristotle the semantics of adjectives and of nouns is expressed through properties. Following the standard representation in first order logic, the predication, i.e. the semantics of verbs is expressed through predicates. For instance, the meaning of *John opened the door with the new key* might be represented by $\exists x\exists y(key(x) \wedge\ new(x) \wedge\ door(y) \wedge\ open(j,y,x))$. It is not as simple to explain the meaning of adverbs (cf. *John* easily *opened the door with the new key*) because to do this requires higher order predicates. But the fundamental problem is elsewhere. As early as in 1879, G. Frege [6] remarked that in the sentences *Bei Platae siegten die Griechen über die Perser* (*By Plataea the Greeks vanquished the Persians*) and *By Platae wurden die Perser von den Griechen besiegt* (*By Plataea the Persians were vanquished by the Greeks*) the verb *siegen* (*vanquish*) in active voice (*siegten*) and in passive voice (*wurden .. besiegt*) express the same predication. It may seem that the problem of semantic representation of the predication invariant of voice variations is purely technical, because it is resolved by the permutation of arguments (in Lambda-notation: $\lambda xy.siegen$ represents *siegten* and $\lambda yx.siegen$ represents *wurden .. besiegt*). This might work more or less, if it were not for two important points: (1) the right interpretation of nouns in argument positions of verbs depends on a preposition/preposition absence rather than on the position number (*siegen*(0:x,0:y) is equivalent to *siegen*(0:y,VON:x)); (2) in both voice forms the first argument is *topical* (the case in point) and the second is *focal* (i.e. related with the topical one through the predication of the verb). In linguistic theories of verbal semantics, in the place of language dependent features, such as prepositions or cases, so called *thematic roles* (or just *roles*), e.g., SUBJECT, OBJECT, AGENT, INSTRUMENT are used (see, e.g., [18] for more details). So the adequate functional type of a verb form should not only specify the right argument and value types, but also specify the arguments' roles. For instance, the type of the active form of *siegen* is $t_1 = (\mathrm{S}|\mathbf{A}^{\mathbf{n}}\mathrm{O}|\mathbf{P}^{\mathbf{n}} \rightarrow \mathbf{s})$ and the type of its passive form is $t_2 = (\mathrm{Obj}^{\mathbf{n}}\mathrm{Agt}^{\mathbf{n}} \rightarrow \mathbf{s})$, where S|**A** is the general role "SUBJECT or AGENT", O|**P** is "OBJECT or PATIENT", OBJ is OBJECT, AGT is AGENT, **n** is the type of nominal meanings and **s** is the type of sentential meanings. Assigning to the verb *siegen* type t_1, one states that applying the meaning of this verb to the meaning of a noun in the S|**A**-position and to the meaning of a noun in the O|**P**-position we obtain a sentential meaning (similar for t_2). In modern linguistic semantical theories such featured types are called *diatheses* (see [12, 13] for discussion and details). In particular, t_1 is the canonical active diathesis of *siegen*, whereas t_2 is its passive diathesis. Now, the abovementioned Frege's remark applied to these diatheses means that the adequate semantics of *siegen* must be invariant with respect to specific diathesis choices. Needless to say, different diatheses of the same verb are differently implemented by the Speaker (in linguistic terms: *have different surface forms*). At the same time, they specify different points of view of the Speaker on the same event. In particular, in the cited example of Frege, the active diathesis t_1 represents the view with Greeks as the topic and Persians as the focus, whereas the passive diathesis represents the inverse view of the same event. The point (2) above may serve to provide a systematic representation of the set of a verb's diatheses as derivatives of one of them, chosen as canonical. Viz., one may identify verbal positions by the corresponding view and derive every diathesis from the canonical one by assigning to every argument a new view and eventually a new role. This transformation is called *diathetic shift*. In the place of "view", we will use a more specific term *communicative rank* (or just *rank*). E.g., denoting by $\vec{\mathsf{T}}$ the rank of the topical argument, by $\odot$ the rank of the focal argument and by $\oplus$ that of the third (*background*) argument, if any, we can describe the derivation of *siegen* to the passive form as the diathetic shift $\text{OBJ} \hookleftarrow \text{O}|\mathbf{P}_{\vec{\mathsf{T}}}$, $\text{AGT} \hookleftarrow \text{S}|\mathbf{A}_{\odot}$, which means that the O|**P**-argument (focal in the canonical diathesis) is moved through assignment of the new rank $\vec{\mathsf{T}}$ to the topical (first) position and obtains the new role OBJ, whereas the S|**A**-argument moves to the (second) focal position and obtains the new role AGT. In these terms, the semantics of a verb must be invariant with respect to diathetic shifts. The next example shows that this semantics is not trivial. In the sentence *John opened the door with the new key* the verb *open* has the canonical diathesis $t_3 = (\text{S}|\mathbf{A}^{\mathbf{n_a}}\text{O}|\mathbf{P}^{\mathbf{n}}\text{INS}^{\mathbf{n}} \rightarrow \mathbf{s_{eff}})$ in which $\mathbf{n_a}$, the type of animated nominals, is a kind of nominal types, INS is the instrumental role whose canonical rank $\oplus$ corresponds to the third argument, and $\mathbf{s_{eff}}$, the sentential type of caused effect, is a kind of sentential types. This verb has the diathesis $t_4 = (\text{AGT}^{\mathbf{n}}\text{OBJ}^{\mathbf{n}} \rightarrow \mathbf{s_{eff}})$ in the sentence *The new key opened the door*. Comparing t_3 and t_4, we see that the S|**A**-argument is absent in t_4, i.e. it is deleted by the corresponding diathetic shift. In order to delete an argument, we will assign to it the *peripheral* rank $\ominus$. So t_4 is derived from t_3 using the diathetic shift $\emptyset \hookleftarrow \text{S}|\mathbf{A}_{\ominus}$, $\text{OBJ} \hookleftarrow \text{O}|\mathbf{P}_{\odot}$, $\text{AGT} \hookleftarrow \text{INS}_{\vec{\mathsf{T}}}$. In general, such diathetic shifts are caused at the surface level by change of voice, nominalization, conversion to infinitive, etc.

DP as feature trees. Now we can state that DP are feature typed terms (generally called *feature trees*), i.e. functional terms in which the arguments of a functor $f^{\mathbf{t}}$ are identified in its type $\mathbf{t}$ by pairwise different sorts of arguments. The abovementioned roles are such sorts. Here is how feature trees are defined.

DEFINITION 1. Let **S** be a set of *sorts* and **T** be a set of *primitive types* with a partial *genericity* order $\preceq$ on it (intuitively, $\mathbf{u} \preceq \mathbf{v}$ means $\mathbf{u}$ is a kind of $\mathbf{v}$). The expressions $\mathbf{t} = (\text{S}_1^{\mathbf{u_1}} \ldots \text{S}_n^{\mathbf{u_n}} \ \rightarrow \ \mathbf{v})$, where $n \geq 0$, $\mathbf{v}, \mathbf{u_1}, \ldots, \mathbf{u_n} \in \mathbf{T}$ and $\text{S}_1, \ldots, \text{S}_n$ are pairwise different sorts, are *functional* (or *composite*) types. If $n = 0$, then $\mathbf{t} = \mathbf{v}$. Let $\mathbf{F} = \{f^{\mathbf{t}}/n \parallel n \geq 0\}$ be a set of typed functors such that the type $\mathbf{t}$ has n argument subtypes (one functor may have several types). Finally, let D be a set of labels we will call *determiners*.
(i) Every expression $d\ f^{\mathbf{v}'}/0$ is a *(determined) feature tree* (*f-tree*) of type $\mathbf{v}$, if $\mathbf{v} \succeq \mathbf{v}'$ and $d \in D$.
(ii) If $t_1^{\mathbf{u}_1'}, \ldots, t_n^{\mathbf{u}_n'}$ are f-trees of primitive types $\mathbf{u}_1', \ldots, \mathbf{u}_n'$, $d \in D$, $f^{\mathbf{t}}/n \in \mathbf{F}$, $\mathbf{t} = (\text{S}_1^{\mathbf{u_1}} \ldots \text{S}_n^{\mathbf{u_n}} \ \rightarrow \ \mathbf{v}')$, $\mathbf{v}' \preceq \mathbf{v}$ and $\mathbf{u}_1' \preceq \mathbf{u_1}, \ldots, \mathbf{u}_n' \preceq \mathbf{u_n}$, then the term $d\ f(\text{S}_1 : t_1, \ldots, \text{S}_n : t_n)$ is an f-tree of type $\mathbf{v}$. □

In order to distinguish the sentences, the verbs, the nouns, the adjectives / adverbs from the semantical objects realizing them, we will use for the latter different terms: *sententials*, *verbals*, *nominals*, *attributors*. We will use the term *semanteme* for DP constants representing words. The next example shows some types and semantemes of these types used in DP.

EXAMPLE 2. **Some nominal types and nominals.** $\mathbf{n}$ (*nominals*), $\mathbf{n_a} \preceq \mathbf{n}$ (*animated nominals*), $\mathbf{n_{count}} \preceq \mathbf{n}$ (*countable nominals*), $\mathbf{n_{ncount}} \preceq \mathbf{n}$ (*uncountable nominals*) are examples of nominal types. $\mathbf{nct} = (\text{STATE}^{\mathbf{a_{grad}}} \rightarrow$

$\mathbf{n_{ncount}}$) (cf. *hot milk*), $\mathbf{ctr} = ($CONTENTS$^{\mathbf{n_{ncount}}}$ FULLNESS$^{\mathbf{a_{grad}}}$QUANT$^{\mathbf{a_{card}}} \rightarrow$ $\mathbf{n_{container}}$) (cf. *two full glasses of beer*) are compound nominal types. MILK$^{\mathbf{nct}}$, SAND$^{\mathbf{nct}}$ are nominals of type **nct**. GLASS$^{\mathbf{ctr}}$, PACK$^{\mathbf{ctr}}$ are nominals of type **ctr**.

Some attributor types: **a** (*attributors*), $\mathbf{a_{grad}} \preceq \mathbf{a}$ (*gradable attributors*, cf. RED$^{\mathbf{a_{grad}}}$, FAST$^{\mathbf{a_{grad}}}$), $\mathbf{a_{degr}} \preceq \mathbf{a}$ (*degree attributors*, cf. VERY$^{\mathbf{a_{degr}}}$, A_BIT$^{\mathbf{a_{degr}}}$), $\mathbf{a_{ord}} \preceq \mathbf{a}$ (*ordinal attributors*, cf. FIRST$^{\mathbf{a_{ord}}}$) $\mathbf{a_{card}} \preceq \mathbf{a}$ (*cardinal attributors*, cf. FIVE$^{\mathbf{a_{card}}}$, MANY$^{\mathbf{a_{card}}}$), $\mathbf{a_{prec}} \preceq \mathbf{a}$ (*precision attributors*, cf. ABOUT$^{\mathbf{a_{prec}}}$, NEARLY$^{\mathbf{a_{prec}}}$).

Verbals have types $(\phi \rightarrow \mathbf{s}')$, where $\mathbf{s}' \preceq \mathbf{s}$ and $\mathbf{s}$ is the *sentential type*. The sorts in ϕ identifying their arguments are divided into *roles* R and *attributes* A. The roles identify the *core* arguments, the attributes identify *circumstantials* and *propositional parameters* denoted PP (see examples below). If a verbal V has several types: $types(V) = \{\mathbf{t_0}, \ldots, \mathbf{t_p}\}$, we call them *diatheses* of V. One of the diatheses, $\mathbf{t_0}$, is selected as *canonical*. Other diatheses are the result of transformations of $\mathbf{t_0}$, called *diathetic shifts*. The diathetic shifts concern only core arguments. Below, representing diatheses, we will denote the roles by R and the attributes by A.

DEFINITION 3. Let $\mathbf{t_0} = (\mathrm{R}_1^{\mathbf{u_1}} \ldots \mathrm{R}_n^{\mathbf{u_n}} \mathrm{A}_1^{\mathbf{v_1}} \ldots \mathrm{A}_m^{\mathbf{v_m}} \rightarrow \mathbf{v})$ be the canonical diathesis of V and $\mathbf{t_i} = ((\mathrm{R}')_1^{\mathbf{u}'_1} \ldots (\mathrm{R}')_k^{\mathbf{u}'_k} \mathrm{A}_1^{\mathbf{v_1}} \ldots \mathrm{A}_m^{\mathbf{v_m}} \rightarrow \mathbf{v}') \in types(V)$ be some other diathesis of V. Then $D_i = (\mathbf{t_i}, \mathbf{d}_i)$ is a *diathetic shift* of $\mathbf{t_0}$ if $\mathbf{d}_i : \{1, \ldots, k\} \stackrel{1-1}{\rightarrow} \{i_1 \ldots, i_k\}$, for $1 \leq i_1 < \ldots < i_k \leq n$, is a bijection preserving types: $\mathbf{u}'_\mathbf{j} = \mathbf{u}_{\mathbf{i_j}}$, $1 \leq j \leq k$. We call this bijection *argument shift* and denote it by $\mathbf{d}_i : k \stackrel{1-1}{\mapsto} n$. $V[\mathbf{d}_i]^{\mathbf{t_i}} =_{df} V^{\mathbf{t_i}}$ is a *derivative* of the canonical form $V^{\mathbf{t_0}}$ through D_i.

EXAMPLE 4. For the verbal OPEN, the argument shift $\{1 \mapsto 2, 2 \mapsto 1, 3 \mapsto 3\}$ corresponds to its diathesis of passive as in the sentence *The door was opened with the key by John's girl-friend* and $\{3 \mapsto 1, 2 \mapsto 2\}$ corresponds to its argument alternation diathesis as in the sentence *The key easily opened the door*.

In the definition of static semantics of DP we will use this representation of verbal derivatives through argument shift and resulting diathesis. Clearly, it can be extracted from the representation of diathetic shifts through rank assignments we showed above. We use the latter representation in examples of DP. In particular, in Fig. 1 we show a DP of the sentence *The new key easily opened the door*. In this figure, the DP is presented in a graphical form where solid lines labeled with roles link verbals to their core arguments and dashed lines labeled with attributes link semantemes to their attributor type arguments: circumstantials for verbals, qualifiers for nominals (e.g., $NEW^{\mathbf{a_{grad}}}$ represents the value of attribute STATE of KEY$^{\mathbf{n}}$). There is also a group of propositional parameters. We don't include them in verbal types because these attributes are common to all verbals. In particular, among the PP-attributes shown in Fig. 1 there are PSTATUS (declarative in Fig. 1), SIGN (*positive*), EVEXTENT, a generalized aspect (*pointwise* • in Fig. 1, *continuous interval* (_)

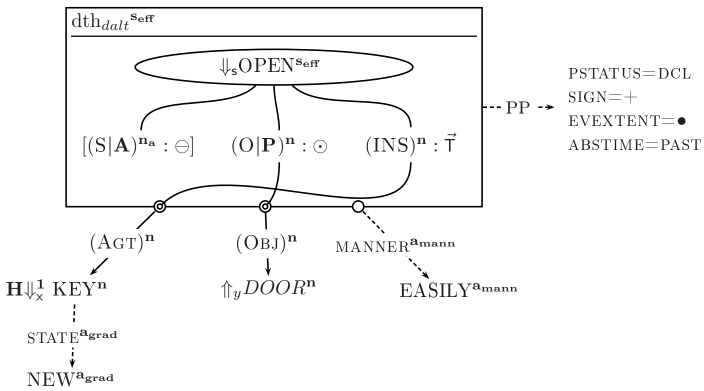

Figure 1. DP of *The new key easily opened the door*

in Fig. 2) and time parameter ABSTIME (PAST in Fig. 1, PRES in Fig. 2). There are other PP we don't show in this figure (cf. RELTIME (*relative time*) $(||t)$, simultaneous with t, in Fig. 2).

Diathetic shifts are represented as assignments to core arguments of new roles and communicative ranks: the canonical assignments are shown inside the box, the new assignments determining the type of the verbal derivative are shown outside the box.

Expressions $\Downarrow_{\mathsf{s}}$, $\mathbf{H} \Downarrow^{\mathbf{1}}_{\mathsf{x}}$, $\Uparrow_y$ are *determiners*. Intuitively, they create or allow access to objects o which have a set value $\|o\|$ called *extension* of o. The most general form of a determiner defined below is $\mathbf{D}_{\mathsf{x}} = \mathbf{QC}_{\mathsf{x}}u$, where x is a *global reference*, u is a *local reference*, $\mathbf{C}_{\mathsf{x}}$ is either one of expressions $\Downarrow^k_{\mathsf{x}}$, $\Downarrow^k_{\mathsf{x}\mathbf{r}\mathsf{y}}$ (*objectification operators*), or $\Uparrow_{\mathsf{x}}$ (*access operator*), and $\mathbf{Q}$ is one of two *modes of access*: $\mathbf{I}$ (*individual*) and $\mathbf{H}$ (*holistic*). Intuitively, the objectification operators $\Downarrow^k_{\mathsf{x}}$, $\Downarrow^k_{\mathsf{x}\mathbf{r}\mathsf{y}}$ create a new object o with extension $\|o\|$ whose cardinality is bounded by k (a number or ω) and bind the global reference x and the local reference u with this object. Besides this, the latter operator relates the object x with a previously created object y through binary relation $\mathbf{r}$: $\mathsf{x}\mathbf{r}\mathsf{y}$. Global and local references differ in scopes: u is visible only in the subplan (i.e. subterm) determined by $\mathbf{D}_{\mathsf{x}}$, whereas x is visible in the discourse starting from this subplan. The access operator $\Uparrow_{\mathsf{x}}$ applies to a global reference x previously bound with an object o by a determiner $\mathbf{D}_{\mathsf{x}}$. Its value depends on the mode of access $\mathbf{Q}$ in $\mathbf{D}_{\mathsf{x}}$: if $\mathbf{Q} = \mathbf{H}$ (holistic access) then the value is $\{o\}$, otherwise it is $\|o\|$ (individual access).

The last feature of DP not yet mentioned is the operator ι whose intuitive reading is "*such object .. that ..*" and which is used to express the meaning of relative and comparative clauses. In Fig. 2 we show the DP of a variant of "donkey sentences" borrowed from [9], which uses this operator. In this example, we see the use of *absolute* individual access determiners (cf. $(\mathbf{I} \Downarrow_{\mathsf{x}_f} u_f)$FARMER$^{\mathbf{n_a}}$), i.e. those which create objects without relating them with other objects. In Fig. 3 is shown a DP using *relativized* determiners, which create objects and relate them with previously created objects through the inclusion relation $\grave{\in}$ (cf. $(\mathbf{H} \Downarrow^1_{\mathsf{y}_f \grave{\in} \mathsf{x}_f} u'_f)(\text{Bob}^{\mathbf{n_a}})_{\mathbf{sh}})$. Intuitively, this

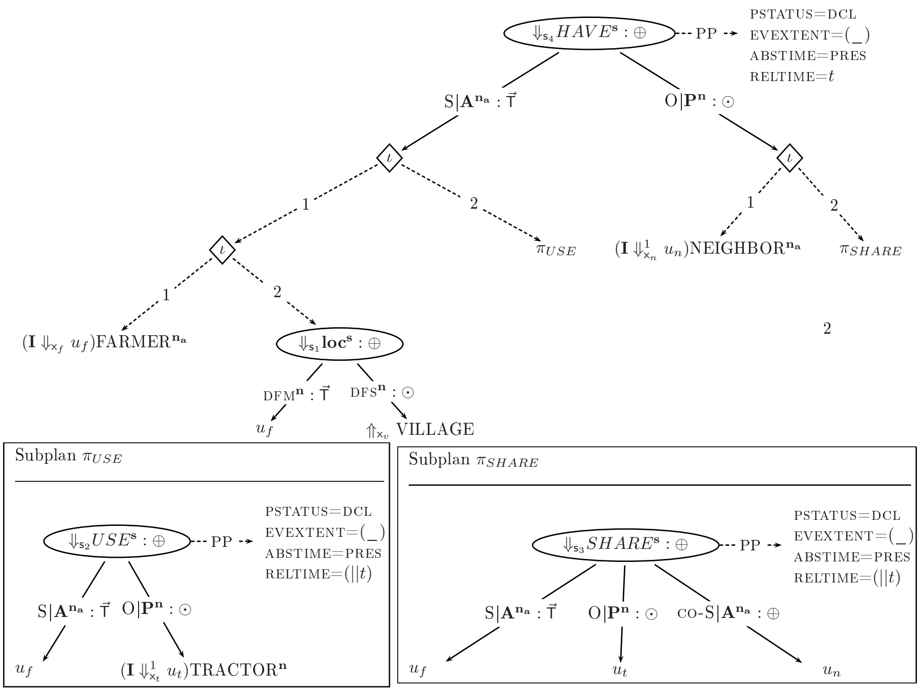

Figure 2. A DP of *Every farmer in the village, who uses a tractor, has a neighbor with whom he shares it.*

determiner states that the object o_B, a realization of the *shifter* constant [1] $(\mathrm{Bob}^{\mathbf{n_a}})_{\mathbf{sh}}$, belongs to the extension of the object o_f, a realization of the semanteme $\mathrm{FARMER}^{\mathbf{n_a}}$ in DP in Fig. 2.

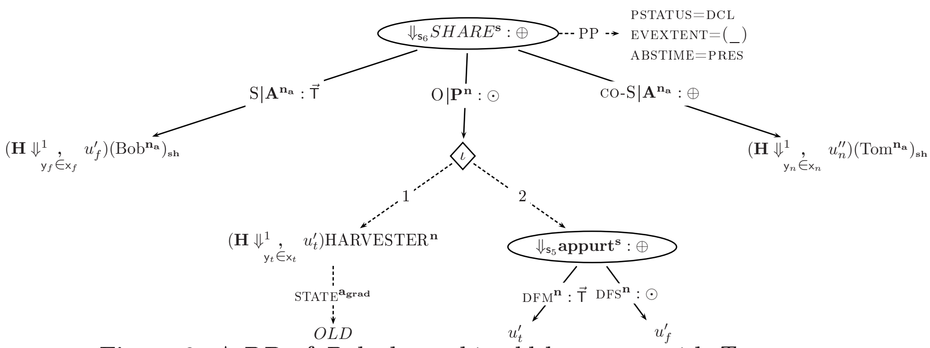

Figure 3. A DP of *Bob shares his old harvester with Tom.*

Before we proceed to the definition of the semantics of DP, we will note two of their special properties which shouldn't pass unnoticed.

Determiners vs. quantifiers. We see that in the DP in our examples the determiners are used in the place of quantifiers. Great difficulties created by

[1] The term proposed by R. Jakobson for the semantemes, such as proper names, whose meaning is completely determined by the context.

quantifiers for compositional semantics definitions, after several decades of debates, have led the semanticians to the pragmatic solution to leave out from semantics the choice of quantifier scope, i.e. to underspecify semantics. The DP determiners avoid this problem due to the joint use of local and global references. The scope of the former, similar to that of quantifiers, is limited by the determined subplan, whereas the scope of the latter extends to the rest of the discourse. Importantly, the *dynamic* semantics of determiners (not included in this paper) is defined so that at the moment, when in a DP $\pi_2 = \mathbf{D}_{\mathsf{y}}\pi'_2$, determined by $\mathbf{D}_{\mathsf{y}} = (\mathbf{Q} \Downarrow^{k}_{\mathsf{y}\in\mathsf{x}} u_2)$, the object y is added to the extension of the object x created in a preceding DP $\pi_1 = \mathbf{D}_{\mathsf{x}}\pi'_1$, determined by $\mathbf{D}_{\mathsf{x}} = (\mathbf{I} \Downarrow^{l}_{\mathsf{x}} u_1)$, the local reference u_1 of $\mathbf{D}_{\mathsf{x}}$ becomes bound by $\{\mathsf{y}\}$. In this way, in the new context, y becomes available in DP π_1.

Attributes vs. properties. As we have noted above, in conventional logical semantics the meaning of the adjectives is expressed using properties of entities. This choice creates semantical problems. One of them was the subject of long and substantial discussions in NL semantics. For instance, in the preceding sentence, the adjectives *long* and *substantial* are related to two different components of the meaning of *discussions*, one *temporal* (a physical characteristics of a process), another *cognitive*. Cf. another example: *his favorite book stood first on the shelf*. Here *first* is related to the position of the *book*, whereas *favorite* is related to its literary qualities. This phenomenon called *copredication* has led to the emergence of formal lexical semantics [16, 1]. It creates a problem of compositional representation of meaning of nouns, providing a correspondence between components of this meaning and the meaning of adjectives modifying the nouns. In DP semantics, the adjectives are interpreted not as properties, but as values of *attributes*. One can see that in DP the subplans representing adjective phrases are in the attribute argument positions of nominals (see the DP in Fig. 4) and the subplans representing adverb phrases are in attribute argument positions of verbals.

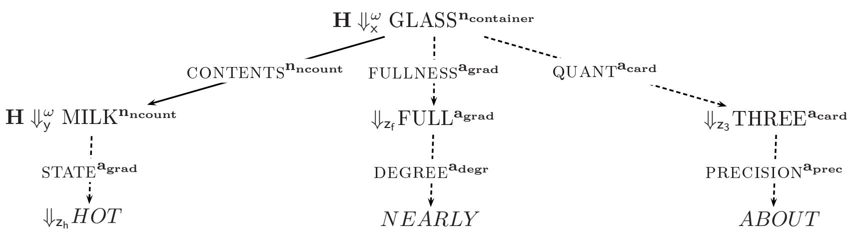

Figure 4. A DP of *about three nearly full glasses of hot milk*.

Below we define the semantics of the attributes as functions on objects. This decision resolves the problem of copredication. Viz., there is no need to stratify the meaning of nominals because different functional attributes may express different components of a primitive nominal meaning: STATE(MILK) = COLD, ORIGIN(MILK) = COW'S. Moreover, in this way the semantic function-argument dependency has the same direction as the syntactic dependency (from noun to adjective), not the opposite, as in conventional logical semantics.

3 Fundamentals of DP Semantics

Dynamic and *static* DP semantics are defined in a subset of set theory extended with specific constants: $LC = \{L_W \mid W$ is a semanteme$\}$ (*lexical class constants*), $R_{\mathbf{g}}$ (*global object references*), $R_{\mathbf{l}}$ (*local object references*), $\mathbf{O}^{\mathbf{t}}$ (*objects* of type $\mathbf{t}$, $\mathbf{O}$ is the union of all $\mathbf{O}^{\mathbf{t}}$), attribute names and some other constants.

Contexts. Both semantics are relative to finite relational structures: the former to *dynamic contexts* (*d-contexts*), the latter to *static contexts* (*s-contexts*).

DEFINITION 5. A *d-context* is a finite structure $\Sigma = (D, I)$, where D is a finite collection of sets and I is a finite function from D into D with four particular restrictions[2]: $\gamma_\Sigma = I{\restriction}R_{\mathbf{g}}$ (*global assignment*), $\lambda_\Sigma = I{\restriction}R_{\mathbf{l}}$ (*local assignment*), $\theta_\Sigma = I{\restriction}\mathbf{O}^{\mathbf{n}}$ (*nominal objects' evaluation*) and $\hbar_\Sigma = I{\restriction}LC$ (*horizon line* of Σ). $\sigma = \langle\gamma_\Sigma, \lambda_\Sigma, \theta_\Sigma, \hbar_\Sigma\rangle$ is the *s-context corresponding to* Σ.

$\gamma_\Sigma(\mathsf{x}) = o$ means that the global reference x is bound with the object o, $\lambda_\Sigma(u) = s$ means that the local reference u is bound with the set s, $\theta_\Sigma(o) = s$ means that the nominal type object o has d-extension $|o|^\Sigma = s$ and $\hbar_\Sigma(L_W) = s$ means that s is the part of the d-extension of L_W accessible in Σ.

Lexical semantics. DP semantics rests upon a set of lexical axioms. The axioms relate a set of functions (*attributes*) with every lexical class constant L_W representing a DP semanteme W. For space reasons, we replace the axioms by simplified postulates. The constant $\perp \notin \mathbf{O}$ used in them is an *"uncertain value"*.

For $\mathbf{u} \in \mathbf{T}$, $LEX(\mathbf{u})$ denotes the set of all DP semantemes of types $(\phi \to \mathbf{u})$ or $\mathbf{u}$. We suppose that every semanteme W has a unique set code $W^\star$.

POSTULATE 6. $L_{\mathbf{u}} \subseteq \mathbf{O}^{\mathbf{u}}$. $\mathbf{u} \preceq \mathbf{v}$ iff $L_{\mathbf{u}} \subseteq L_{\mathbf{v}}$. $L_W \subseteq L_{\mathbf{u}}$ for $W \in LEX(\mathbf{u})$.

POSTULATE 7. The extension $\|o\|$ of an attributor type object $o \in \mathbf{O}^{\mathbf{u}}$, $\mathbf{u} \preceq \mathbf{a}$, is a semanteme code: $\|o\| \in \{W^\star \mid W \in LEX(\mathbf{u})\}$.

POSTULATE 8. For all semantemes $W \in LEX(\mathbf{u})$, the classes L_W have the same attributes. The set of these attributes is denoted $Att(\mathbf{u})$.

POSTULATE 9. For every attribute $\mathrm{A} \in Att(\mathbf{u})$, there is an attributor type $\mathbf{v} \preceq \mathbf{a}$ such that: $\mathrm{A} : \mathbf{O}^{\mathbf{u}} \to (\mathbf{O}^{\mathbf{v}} \cup \{\perp\})$, if $Att(\mathbf{v}) \neq \emptyset$, and $\mathrm{A} : \mathbf{O}^{\mathbf{u}} \to (\{W^\star \mid W \in LEX(\mathbf{v})\} \cup \{\perp\})$, if $Att(\mathbf{v}) = \emptyset$. This function (denoted $\mathrm{A}^{\mathbf{v}}$) is finite in the sense that $\{o \mid \mathrm{A}(o) \neq \perp\}$ is a finite set. $\mathbf{v}$ is its *value type* . For attributor type objects $o \in \mathbf{O}^{\mathbf{u}}$, $\mathbf{u} \preceq \mathbf{a}$, and for their attributes $\mathrm{A}^{\mathbf{v}} \in Att(\mathbf{u})$, $o.\mathrm{A} =_{df} \|\mathrm{A}(o)\|$ if $\mathrm{A}(o) \neq \perp$.

If $Att(\mathbf{u}) = \{\mathrm{A}_1^{\mathbf{v_1}}, \ldots, \mathrm{A}_m^{\mathbf{v_m}}\}$, then the types in $DT(\mathbf{u}) =_{df} \{\mathbf{v}_1, \ldots, \mathbf{v}_m\}$ are *immediately dependent* on $\mathbf{u}$ (denoted $\mathbf{v}_i \lhd^{imm} \mathbf{u}$). Let $\unlhd$ (*lexical dependency*) be the reflexive-transitive closure of $\lhd^{imm}$. So $\mathbf{v} \unlhd \mathbf{u}$ implies $\mathbf{v} \preceq \mathbf{a}$.

POSTULATE 10. $\unlhd$ is a partial order.

There are also axioms defining a hierarchy of primitive types. We only cite

[2] $f{\restriction}S = \{\langle x_1, x_2\rangle \in f \mid x_1 \in S\}$.

two of their consequences and give several examples.
1. There are three $\preceq$-maximal (i.e. most general) types: $\mathbf{s}$, $\mathbf{n}$ and $\mathbf{a}$.
2. $\mathbf{a_{degr}}, \mathbf{a_{prec}}$ are $\trianglelefteq$-minimal attributor types: $DT(\mathbf{a_{degr}}) = DT(\mathbf{a_{prec}}) = \emptyset$.

EXAMPLE 11. The types in Example 2 have the following properties. $DT(\mathbf{n_{ncount}}) = \{\mathbf{a_{grad}}\}$. $\mathbf{a_{grad}} \in DT(\mathbf{n}) \cap DT(\mathbf{s})$ and $DT(\mathbf{a_{grad}}) = \{\mathbf{a_{degr}}\}$. $\mathbf{a_{ord}} \in DT(\mathbf{n_{count}})$ and $DT(\mathbf{a_{ord}}) = \{\mathbf{a_{prec}}\}$. $\mathbf{a_{card}} \in DT(\mathbf{n_{meas}}) \cap DT(\mathbf{n_{count}})$ and $DT(\mathbf{a_{card}}) = \{\mathbf{a_{prec}}\}$.

One can see that due to these axioms with every attributor DP is uniquely related a set of constraints on values and extensions of attributes.

EXAMPLE 12. The semanteme GLASS in the DP in Fig. 4 has one core CONTENTS-argument and two attributes: $Att(\mathbf{n_{container}}) = \{\text{FULLNESS}^{\mathbf{a_{grad}}}, \text{QUANT}^{\mathbf{a_{card}}}\}$. Respectively, the system of constraints for GLASS is defined as $AC(\text{FULLNESS}^{\mathbf{a_{grad}}} = \pi_1, \text{QUANT}^{\mathbf{a_{card}}} = \pi_2) = AC(\text{FULLNESS}^{\mathbf{a_{grad}}} = \pi_1) \cup AC(\text{QUANT}^{\mathbf{a_{card}}} = \pi_2)$, where π_1 and π_2 are the two attributor subplans of this DP: FULLNESS-branch and QUANT-branch. The components are computed recursively: $AC(\text{DEGREE} = \text{NEARLY}) = \{\text{DEGREE}(o_f) = NEARLY^\star, \|o_f\| = FULL^\star\}$ for $o_f = \gamma(\mathsf{z_f})$, $AC(\text{FULLNESS}^{\mathbf{a_{grad}}} = \pi_1) = \{\text{FULLNESS}(o) = o_f\} \cup AC(\text{DEGREE} = \text{NEARLY})$ for $o = \gamma(\mathsf{x})$. Similar for $AC(\text{QUANT}^{\mathbf{a_{card}}} = \pi_2)$.

Shifted product. DP semantics reduces all verbal's derivatives to its canonical form. For this it uses a special product allowing to relate their arguments.

DEFINITION 13. Let $n > 0$, $\mathbf{d} : k \overset{1-1}{\mapsto} n$ be an argument shift and $s_1, \ldots, s_n$ be a sequence of sets. The *shifted product* of this sequence (under shift $\mathbf{d}$) is:

$$\prod_{1 \le i \le k}^{\mathbf{d}} s_i =_{df} M_1 \times \ldots \times M_n,$$

where $M_i = s_{\mathbf{d}^{-1}(i)}$ for $i \in range(\mathbf{d})$ and $M_i = \{\perp\}$ otherwise.

4 Static Semantics

In this section we define in parallel the syntax[3] and the static semantics of DP. The correspondence between d- and s-contexts being inessential for this semantics, we fix an s-context $\sigma = \langle \Gamma, \Lambda, \Theta, H \rangle$ in which, for every DP π, will be defined its *s-extension* $\|\pi\|^\sigma$. So Γ is a global assignment, Λ is a local assignment, Θ is a nominal objects' evaluation and H is a horizon line. As we shall see, every composite subplan π of a DP is uniquely identified by a global reference x introduced by a determiner: $\pi = \mathbf{D}_{\mathsf{x}}\pi'$. The static semantics $\|\pi\|^\sigma$ will be defined through the extension $\|\Gamma(\mathsf{x})\|^\sigma$ of the object $\Gamma(\mathsf{x})$.
I. Primitives.
I.1. Lexical classes. For a non-attributor semanteme W, $\|L_W\|^\sigma = H(L_W)$.
I.2. Null plans (intuitively, corresponding to existentially bound arguments).
For a null nominal plan $\pi = \Downarrow_{\mathsf{x}} 0^{\mathbf{n}}$ (**Ex:** *Testamentary succession*$_{\text{OBJ}:\Downarrow_{\mathsf{x}}\, 0^{\mathbf{n}}}$ *goes to Mary*),
$\|\pi\|^\sigma = \|\Gamma(\mathsf{x})\|^\sigma$, where $\|\Gamma(\mathsf{x})\|^\sigma = \{\perp\}$.
For a null attributor plan $\pi = \Downarrow_{\mathsf{x}} 0^{\mathbf{a}}$ (**Ex:** *happy*$_{\text{DEGREE}:0^{\mathbf{a_{degr}}}}$ *as goblin*),
$\|\pi\|^\sigma = \|\Gamma(\mathsf{x})\|^\sigma$, where $\|\Gamma(\mathsf{x})\|^\sigma = \perp$.

[3] Because of space limits we omit the rules of visibility of references.

I.3. Shifter plans. Let $\pi = \Downarrow_{\mathsf{x}} (\mathrm{K}^{\mathbf{n}'})_{\mathbf{sh}}$, where $(\mathrm{K}^{\mathbf{n}'})_{\mathbf{sh}}$ is a nominal shifter constant of type $\mathbf{n}'$ (e.g., $(\mathbf{speaker}^{\mathbf{n_a}})_{\mathbf{sh}}$, $(\mathrm{John}^{\mathbf{n_a}})_{\mathbf{sh}}$). Then:
$\|\pi\|^\sigma = \|\Gamma(\mathsf{x})\|^\sigma$, where $\|\Gamma(\mathsf{x})\|^\sigma = \{((\mathrm{K})_{\mathbf{sh}})^\star\}$.
I.4. Reference plans. Let $u^{\mathbf{t}}$ and $\mathsf{x}^{\mathbf{t}}$ be local and global references.
$\|\pi\|^\sigma = \|\Lambda(u)\|^\sigma$ for $\pi = u$.
$\|\pi\|^\sigma = \|\pi_0\|^\sigma$ for $\pi = \Uparrow_{\mathsf{x}^{\mathbf{t}}}$ and $\pi_0 = \mathbf{D}_{\mathsf{x}}\pi'$, $\mathbf{D}_{\mathsf{x}}$ being a determiner.
I.5. Primitive attributor plans. $\pi = W$, where $W \in LEX(\mathbf{v})$ and $\mathbf{v} \preceq \mathbf{a}$ is a $\trianglelefteq$-minimal attributor type (e.g. $\mathbf{a_{degr}}$, $\mathbf{a_{prec}}$), are the only nonreferenced DP. For such DP, $\|\pi\|^\sigma = W^\star$.
II. Compound DP.
Sentential plans.
II.1. Unit sentential plans. Let $\pi = \Downarrow_{\mathsf{x}} V[\mathbf{d}](\mathrm{R}_1 : \pi_1, \ldots, \mathrm{R}_k : \pi_k,\ \mathrm{A}_1 : \pi'_1, \ldots, \mathrm{A}_m : \pi'_m)$ be a sentential DP in which $\pi'_i = \Downarrow_{\mathsf{x}_i} \pi''_i$, $1 \le i \le m$, are composite attributor DP. Then:
$\|\pi\|^\sigma = \|\Gamma(\mathsf{x})\|^\sigma$,
$\|\Gamma(\mathsf{x})\|^\sigma = \prod\limits_{1\le i\le k}^{\mathbf{d}} \|\pi_i\|^\sigma$.
$\Gamma(\mathsf{x}) \in \|L_{\mathbf{V}}\|^\sigma$,
$\mathrm{A}_i(\Gamma(\mathsf{x})) = \Gamma(\mathsf{x}_i)$ and $\Gamma(\mathsf{x}).\mathrm{A}_i = \|\pi'_i\|^\sigma$, $1 \le i \le m$.
II.2. Coordinated sentential plans. Let $\pi = \Downarrow_{\mathsf{x}} \mathcal{C}^{(n)}(\pi_1, \ldots, \pi_n)$, where $n > 1$ and $\pi_i = \Downarrow_{\mathsf{x}_i} \pi'_i$ are unit sentential DP of sentential types $\mathbf{s_i}$, $1 \le i \le n$. Then:
$\|\pi\|^\sigma = \|\Gamma(\mathsf{x})\|^\sigma$, where $\|\Gamma(\mathsf{x})\|^\sigma = \langle\Gamma(\mathsf{x}_1), \ldots, \Gamma(\mathsf{x}_n)\rangle$,
$\|\Gamma(\mathsf{x}_i)\|^\sigma = \|\pi'_i\|^\sigma, 1 \le i \le n$.
Nominal plans.
II.3. Absolute unit determined nominal plans. Let $\pi = \mathbf{D}_{\mathsf{x}}\hat{\pi}$, where $\mathbf{D}_{\mathsf{x}} = (\mathbf{Q} \Downarrow^{\mathbf{k}}_{\mathsf{x}} u)$ is a determiner in which $\mathbf{Q} \in \{\mathbf{H}, \mathbf{I}\}$, $\mathsf{x}^{\mathbf{n}'}$ is a global reference, u is a local reference, $\mathbf{k}$ is a number or ω, $N^{\mathbf{t}}$ is a nominal of type $\mathbf{t} = (\mathrm{S}_1^{\mathbf{n_1}} \ldots \mathrm{S}_k^{\mathbf{n_k}} \mathrm{A}_1^{\mathbf{v_1}} \ldots \mathrm{A}_m^{\mathbf{v_m}} \to \mathbf{n}')$, $\hat{\pi} = N^{\mathbf{t}}(\mathrm{S}_1 : \pi_1, \ldots, \mathrm{S}_k : \pi_k, \mathrm{A}_1 : \pi'_1, \ldots, \mathrm{A}_m : \pi'_m)$ is a determinerless nominal DP, where $\mathbf{n}' \preceq \mathbf{n}$, $\pi_i = \mathbf{D}_{\mathsf{x}_i}\hat{\pi}_i$, $1 \le i \le k$, are core argument nominal DP and $\pi'_j = \Downarrow_{\mathsf{y}_j} \hat{\pi}'_j$, $1 \le j \le m$, are composite attributor DP (see the DP in Fig. 4 and Example 12). Then:
$\|\pi\|^\sigma = \{\Gamma(\mathsf{x})\}$, if $\mathbf{Q} = \mathbf{H}$, and $\|\pi\|^\sigma = \|\Gamma(\mathsf{x})\|^\sigma$, if $\mathbf{Q} = \mathbf{I}$,
$\|\Gamma(\mathsf{x})\|^\sigma = \Theta(\Gamma(\mathsf{x}))$, $\perp \in \|\Gamma(\mathsf{x})\|^\sigma$ and $card(\|\Gamma(\mathsf{x})\|^\sigma) \le \mathbf{k}$,
$\Gamma(\mathsf{x}) \in \|L_N\|^\sigma$,
$\mathrm{S}_i(\Gamma(\mathsf{x})) = \Gamma(\mathsf{x}_i)$, $1 \le i \le k$.
$\mathrm{A}_j(\Gamma(\mathsf{x})) = \Gamma(\mathsf{y}_j)$ and $\Gamma(\mathsf{x}).\mathrm{A}_j = \|\pi'_j\|^\sigma$, $1 \le j \le m$.
II.4. Relativized unit determined nominal plans. Let $\pi = \mathbf{D}_{\mathsf{x}}\pi_1$, where $\mathbf{D}_{\mathsf{x}} = (\mathbf{Q} \Downarrow^{\mathbf{k}}_{\mathsf{xry}} u)$ is a determiner in which $\mathbf{Q} \in \{\mathbf{H}, \mathbf{I}\}$, $\mathbf{r} \in \{\dot{\in}, \sim, \subset, /, \ldots\}$, π_1 is a determinerless nominal plan and y is a global object reference identifying in the preceding discourse a nominal plan $\mathbf{D}_{\mathsf{y}}\pi_0$ with determiner $\mathbf{D}_{\mathsf{y}} = (\mathbf{Q_0} \Downarrow^{\mathbf{k_0}}_{\mathsf{y}} u_0)$ (see the DP in Fig. 2). Then $\|\pi\|^\sigma$ is defined as in the preceding case. Besides this, the following $\mathbf{r}$-conditions also hold:
$\|\mathbf{r}\|^\sigma(\Gamma(\mathsf{x}), \Gamma(\mathsf{y}))$ if $\mathbf{r} \in \{\sim, \subset, /, \ldots\}$,
$\Gamma(\mathsf{x}) \in \|\Gamma(\mathsf{y})\|^\sigma$, $\Lambda(u_0) = \{\Gamma(\mathsf{x})\}$ and $card(\|\Gamma(\mathsf{y})\|^\sigma) \le \mathbf{k_0}$ if $\mathbf{r} = \dot{\in}$.
II.5. Relative determined nominal plans. Let $\pi = \iota_{\mathrm{R}}(\pi_0 \mid \hat{\pi}_0)$, where

$\pi_0 = \mathbf{D}_{\mathsf{x}}\pi'_0$ is a unit determined nominal plan, u is the local reference in $\mathbf{D}_{\mathsf{x}}$, R is a role and $\hat{\pi}_0 = \Downarrow_{\mathsf{y}} V[\mathbf{d}](\mathrm{R}_1 : \hat{\pi}_1, \ldots, \mathrm{R}_i : u, \ldots, \mathrm{R}_k : \hat{\pi}_k, \mathrm{A}_1 : \hat{\pi}'_1, \ldots, \mathrm{A}_m : \hat{\pi}'_m)$ is a sentential plan such that $\mathrm{R}_i = \mathrm{R}$. Let also $I^{\sigma}_{\mathrm{R}}(\hat{\pi}_0) = \{x \mid (\exists y_1, \ldots, y_n)(\langle y_1, \ldots, y_n\rangle \in \|\Gamma(\mathsf{y})\|^{\sigma} \;\&\; x = y_{d^{-1}(i)})\}$. Then:
$\|\Gamma(\mathsf{x})\|^{\sigma} = \|\pi_0\|^{\sigma} \cap I^{\sigma}_{\mathrm{R}}(\hat{\pi}_0)$ and
$\|\pi\|^{\sigma} = \{\Gamma(\mathsf{x})\}$, if $\mathbf{Q} = \mathbf{H}$, and $\|\pi\|^{\sigma} = \|\Gamma(\mathsf{x})\|^{\sigma}$, if $\mathbf{Q} = \mathbf{I}$.
If π_0 is a relativized unit determined nominal plan (i.e. $\mathbf{D}_{\mathsf{x}} = \mathbf{Q} \Downarrow^{\mathbf{k}}_{\mathsf{xry}} u$), then the **r**-conditions also hold.
Ex: Relative and comparative clauses.
II.6. Aggregate nominal plans. Let $\pi = \mathbf{D}_{\mathsf{x}}\mathcal{A}(\pi_1, \ldots, \pi_n)$, where $\mathbf{D}_{\mathsf{x}} = \mathbf{Q} \Downarrow^{\mathbf{k}}_{\mathsf{x}} u$ and $\pi_i = \mathbf{D}_{\mathsf{x}_i}\pi'_i$, $1 \le i \le n$, are determined nominal DP. Then:
$\|\Gamma(\mathsf{x})\|^{\sigma} = \Theta(\Gamma(\mathsf{x}))$ and $\Gamma(\mathsf{x}_1), \ldots, \Gamma(\mathsf{x}_n) \in \|\Gamma(\mathsf{x})\|^{\sigma}$ if $\mathbf{k} = \omega$,
$\|\Gamma(\mathsf{x})\|^{\sigma} = \{\Gamma(\mathsf{x}_1), \ldots, \Gamma(\mathsf{x}_n)\}$ if $\mathbf{k} = n$,
$\|\pi\|^{\sigma} = \{\Gamma(\mathsf{x})\}$, if $\mathbf{Q} = \mathbf{H}$, and $\|\pi\|^{\sigma} = \|\Gamma(\mathsf{x})\|^{\sigma}$, if $\mathbf{Q} = \mathbf{I}$.
Ex: *(Students*$_{\Downarrow_{\mathsf{x}_1}}$ *and professors*$_{\Downarrow_{\mathsf{x}_2}}$*)*$_{\Downarrow_{\mathsf{x}}}$ *went on strike.*

Attributor plans.
II.7. Lexicalized attributor plans. Let $\pi = \Downarrow_{\mathsf{x}} W^{\mathbf{t}}(\mathrm{A}_1 : \pi_1, \ldots, \mathrm{A}_m : \pi_m)$ be a DP in which $\mathbf{t} = (\mathrm{A}_1^{\mathbf{v_1}} \ldots \mathrm{A}_m^{\mathbf{v_m}} \rightarrow \mathbf{u})$, $\mathbf{u} \preceq \mathbf{a}$, and π_i are attributor DP, $1 \le i \le m$. Then:
$\|\pi\|^{\sigma} = \|\Gamma(\mathsf{x})\|^{\sigma} = W^{\star}$,
$\mathrm{A}_i(\Gamma(\mathsf{x})) = \Gamma(\mathsf{x}_i)$, if $\pi_i = \Downarrow_{\mathsf{x}_i} \pi'_i$, and $\mathrm{A}_i(\Gamma(\mathsf{x})) = \|\pi_i\|^{\sigma}$ otherwise, $1 \le i \le m$,
$\Gamma(\mathsf{x}).\mathrm{A}_i = \|\pi_i\|^{\sigma}$, $1 \le i \le m$.
Ex: See the DP in Fig. 4 and Example 12.
II.8. Relative attributor plans. Let $\pi = \iota\left(\Downarrow_{\mathsf{x}} 0^{\mathbf{t}} \mid \pi_1\right)$ be a relative attributor plan in which $\mathbf{u} \preceq \mathbf{a}$ is an attributor type, $\mathsf{x}^{\mathbf{u}}$ is a global reference and $\pi_1 = \Downarrow_{\mathsf{y}} \pi'_1$ is a sentential type DP. Then:
$\|\pi\|^{\sigma} = \|\Gamma(\mathsf{x})\|^{\sigma} = \perp$,
$\|\pi_1\|^{\sigma} = \|\Gamma(\mathsf{y})\|^{\sigma}$,
$\|\mathbf{rel}\|^{\sigma}(\Gamma(\mathsf{x}), \Gamma(\mathsf{y}))$ for a special relation **rel**.
Ex: *He was so*$_{\Downarrow_{\mathsf{x}}(0^{\mathbf{a_{degr}}})}$ *glad, that ...*

5 On Dynamic DP Semantics

Dynamic semantics is defined through translation$\lceil .. \rceil$: for a discourse $\delta = (\pi_1, \ldots, \pi_n)$, $\lceil \delta \rceil = \lceil \pi_1 \rceil \ldots \lceil \pi_n \rceil$ is a process which, when applied to a starting context Σ_0, computes *dynamic extensions* of DP: $|\delta|_{\Sigma_0} = (|\pi_1|^{\Sigma_1}_{\Sigma_0}, |\pi_2|^{\Sigma_2}_{\Sigma_1}, \ldots, |\pi_n|^{\Sigma_n}_{\Sigma_{n-1}})$ ($|\pi_i|^{\Sigma_i}_{\Sigma_{i-1}}$ is the *d-extension* of π_i in Σ_i computed starting from Σ_{i-1}). The translation and the transitions are rather technical and will be published elsewhere. Here we only illustrate it by the process corresponding to the discourse $\delta = (\pi_1, \pi_2)$ where π_1 and π_2 are DP in Fig. 2,3.

Its intermediate data are shown in Tables 1,2 with columns: Context (current d-context), GRef (global object reference identifying a subplan), OId (identity of the created object), d-Extension elements (elements added to the d-extension of the object), LRef (local object reference), LVal (current value of the local object reference), Attributes (attribute value extension) and Semanteme (the root semanteme of the subplan). This computation executes two processes: $\lceil \pi_1 \rceil = p_1$ (see Table 1) and $\lceil \pi_2 \rceil = p_2$ (see Table 2). The computation of

Context	GRef	OId	d-Extension elements	LRef	LVal	Attributes	Semanteme
Σ_0	x_v	$o_v \in \mathbf{O^n}$	$(\mathrm{v})^{\star}_{\mathbf{sh}}$				VILLAGE
Σ_1	x_f	$o_f \in \mathbf{O^{n_a}}$	$\perp$	u_f	$\{\perp\}$		FARMER
Σ_2	s_1	$o_{loc} \in \mathbf{O^s}$	$\langle \mathrm{DFM} : \perp, \mathrm{DFS} : o_v \rangle$				**loc**
Σ_3	x_t	$o_t \in \mathbf{O^n}$	$\perp$	u_t	$\{\perp\}$		TRACTOR
Σ_4	s_2	$o_u \in \mathbf{O^s}$	$\langle \mathrm{S}\vert\mathbf{A} : \perp, \mathrm{O}\vert\mathbf{P} : \perp \rangle$			$o_u.\mathrm{PSTATUS} = \mathrm{DCL}^{\star}$, etc.	USE
Σ_5	x_n	$o_n \in \mathbf{O^{n_a}}$	$\perp$	u_n	$\{\perp\}$		NEIGHBOR
Σ_6	s_3	$o_{sh} \in \mathbf{O^s}$	$\langle \mathrm{S}\vert\mathbf{A} : \perp, \mathrm{O}\vert\mathbf{P} : \perp, \mathrm{CO\text{-}S}\vert\mathbf{A} : \perp \rangle$			$o_u.\mathrm{PSTATUS} = \mathrm{DCL}^{\star}$, etc.	SHARE
Σ_7	s_4	$o_h \in \mathbf{O^s}$	$\langle \mathrm{S}\vert\mathbf{A} : \perp, \mathrm{O}\vert\mathbf{P} : \perp \rangle$			$o_h.\mathrm{PSTATUS} = \mathrm{DCL}^{\star}$, etc.	HAVE

Table 1. Computation for the first DP π_1.

Context	GRef	OId	d-Extension elements	LRef	LVal	Attributes	Semanteme
Σ_8	y_f	$o_B \in \mathbf{O^{n_a}}$	$(\mathrm{Bob})^{\star}_{\mathbf{sh}}$	u'_f	$\{o_B\}$		$(\mathrm{Bob})_{\mathbf{sh}}$
	x_f	o_f	$\perp, o_B$	u_f	$\{o_B\}$		
	s_2	o_u	$\langle \mathrm{S}\vert\mathbf{A} : o_B, \mathrm{O}\vert\mathbf{P} : \perp \rangle$				USE
	s_4	o_h	$\langle \mathrm{S}\vert\mathbf{A} : o_B, \mathrm{O}\vert\mathbf{P} : o_n \rangle$				HAVE
Σ_9	y_t	$o_{hv} \in \mathbf{O^n}$	o_{hv}	u'_t	$\{o_{hv}\}$	$o_{hv}.\mathrm{STATE} = \mathrm{OLD}^{\star}$	HARVESTER
	x_t	o_t	$\perp, o_{hv}$	u_t	$\{o_{hv}\}$		TRACTOR
	s_1	o_u	$\langle \mathrm{S}\vert\mathbf{A} : o_B, \mathrm{O}\vert\mathbf{P} : o_{hv} \rangle$				USE
Σ_{10}	s_5	$o_{appurt} \in \mathbf{O^s}$	$\langle \mathrm{DFM} : o_{hv}, \mathrm{DFS} : o_B \rangle$				**appurt**
Σ_{11}	y_n	$o_T \in \mathbf{O^{n_a}}$	$(\mathrm{Tom})^{\star}_{\mathbf{sh}}$	u'_n	$\{o_T\}$		$(\mathrm{Tom})_{\mathbf{sh}}$
	x_n	o_n	$\perp, o_T$	u_n	$\{o_T\}$		NEIGHBOR
	s_3	o_{sh}	$\langle \mathrm{S}\vert\mathbf{A} : o_B, \mathrm{O}\vert\mathbf{P} : o_{hv}, \mathrm{CO\text{-}S}\vert\mathbf{A} : o_T \rangle$				SHARE
Σ_{12}	s_6	o'_{sh}	$\langle \mathrm{S}\vert\mathbf{A} : o_B, \mathrm{O}\vert\mathbf{P} : o_{hv}, \mathrm{CO\text{-}S}\vert\mathbf{A} : o_T \rangle$			$o'_{sh}.\mathrm{PSTATUS} = \mathrm{DCL}^{\star}$, etc.	SHARE

Table 2. Computation corresponding to the second DP π_2.

$p_1 = \lceil \pi_1 \rceil$ (see Table 1) is started in context Σ_0 in which there is an object $o_v = \gamma_{\Sigma_0}(\mathsf{x}_v)$ referenced by $\Uparrow_{\mathsf{x}_v}$ (*<u>the</u> village*). Then, in the course of seven consecutive transitions, it creates a new object o for each subplan identified by its determiner $\mathbf{D}_{\mathsf{x}}$, binds the global reference x with o and adds the object to the accessible subset $\hbar_{\Sigma_1}(L_W)$ of the lexical class L_W corresponding to the head semanteme W of the subplan. In the case where W is a verbal, the process adds new facts to the shifted product related with L_W (the element of the column "Semanteme" identifies W and the corresponding subplan). For instance, in the transition to Σ_3 the process creates an object $o_t \in \mathbf{O^n}$ for TRACTOR with the *uncertain* extension $\{\perp\}$ (cf. with the transition to Σ_9, where it creates the *certain* extension $\{o_{hv}\}$). This is explained by the difference of access modes in the two determiners: *individual* **I** for TRACTOR and *holistic* **H** for HARVESTER. This difference manifests itself in the computation of p_2 (see Table 2). Viz., due to the determiner $(\mathbf{H} \Downarrow^1 \underset{\mathsf{y}_f \in \mathsf{x}_f}{,} \; u'_f)$ applied to $(\mathrm{Bob}^{\mathbf{n_a}})_{\mathbf{sh}}$, this computation changes Σ_7 to Σ_8, creates $o_B = \gamma_{\Sigma_8}(\mathsf{y}_f) \in \mathbf{O^{n_a}}$ with extension $\theta_{\Sigma_8}(o_B) = \{(\mathrm{Bob})^{\star}_{\mathbf{sh}}\}$, and, due to the relativized reference $\mathsf{y}_f \overset{,}{\in} \mathsf{x}_f$, adds o_B to the extension $|o_f|^{\Sigma_8}$ and to $\hbar_{\Sigma_8}(L_{FARMER})$, and binds the local reference u_f with $\{o_B\}$ ($\lambda_{\Sigma_8}(u_f) = \{o_B\}$), whereby the shifted products for USE and HAVE are recomputed: $\langle \mathrm{S}|\mathbf{A} : o_B,\ \mathrm{O}|\mathbf{P} : \perp \rangle$ is added to the former and $\langle \mathrm{S}|\mathbf{A} : o_B,\ \mathrm{O}|\mathbf{P} : o_n \rangle$ is added to the latter. A similar effect is seen in the transitions to Σ_9 and to Σ_{11}.

This example shows that the individual determiners express a specific plurality-through-evidence: an object o_2 gets to the set-extension of a nominal object o_1 only due to a relativized determiner with relation $\mathsf{y} \overset{,}{\in} \mathsf{x}$, where o_1 binds x and o_2 binds y, i.e. only due to a witness of this inclusion in the discourse.

Properties of DP semantics. The dynamic and the static DP semantics coincide in the corresponding contexts.

THEOREM 14. *1. Let* $\delta = (\pi_1, \ldots, \pi_n)$ *be a discourse,* Σ_0 *be an initial d-context,* $|\delta|_{\Sigma_0} = (|\pi_1|_{\Sigma_0}^{\Sigma_1}, |\pi_2|_{\Sigma_1}^{\Sigma_2}, \ldots, |\pi_n|_{\Sigma_{n-1}}^{\Sigma_n})$ *be the d-semantics of* δ *relative to* Σ_0 *and* $\sigma_i = \langle \gamma_{\Sigma_i}, \lambda_{\Sigma_i}, \theta_{\Sigma_i}, \hbar_{\Sigma_i} \rangle$ *be the s-contexts corresponding to d-contexts* Σ_i. *Then* $|\pi_i|_{\Sigma_{i-1}}^{\Sigma_i} = \|\pi_i\|^{\sigma_i}$ *for all* $i, 0 < i \leq n$.

The dynamic DP semantics is monotonic:

THEOREM 15. *Let* $\delta^\infty = (\pi_1, \pi_2, \ldots)$ *be an infinite discourse,* $|\delta|_{\Sigma_0}^\infty = (|\pi_1|_{\Sigma_0}^{\Sigma_1}, |\pi_2|_{\Sigma_1}^{\Sigma_2}, \ldots)$ *and* $\Sigma' \leq^\circ \Sigma''$ *iff* $|o|^{\Sigma'} \subseteq |o|^{\Sigma''}$ *and* $\hbar_{\Sigma'}(L) \subseteq \hbar_{\Sigma''}(L)$ *for all objects and classes. Then* $\Sigma_0 \leq^\circ \Sigma_1 \leq^\circ \Sigma_2 \leq^\circ \ldots$ *is an increasing chain.*

6 Conclusion

One can see that the Speaker's stance discourse semantics outlined in this paper is different from all logical DRT-like semantics of discourse (cf. [7, 8, 9, 14]). The anaphora resolution is not included into the DP semantics because the referential relations are explicitly marked in DP using its determiners. Some of the referential relations established by these determiners, such as co-reference $\sim$, and attribute value comparison relations $<, >, =$, as well as the signs $+, -$ of verbal objects may introduce conflicts in the contexts. Checking of probable inconsistencies in the contexts is not required in DP semantics. This makes possible to apply it to correctly constructed DP with contradictory meaning, which is impossible in all kinds of logical theories of discourse.

Due to object-orientation, the DP semantics goes without quantifiers. Even so, there are certain similarities between the conventional quantifiers and the DP determiners. Creation of an object ($\gamma(\mathsf{x}) = o$) is an analog of the existential quantifier. It is closer than the logical quantifier to the natural language "existence": *every entity mentioned in the discourse exists.* The access modes **H** and **I** correspond to two different concepts of universal quantification. The former, holistic, was always a problem to express in the traditional logical semantics. It allows one to adequately express the meaning of noun phrases as in *John likes* $(books)_{(\mathbf{H}\Downarrow_{\mathsf{x}}^{\omega} u)BOOK}$ and provides a holistic interpretation for mass nominals as in *He needs more* $(water)_{\mathbf{H}\Downarrow_{\mathsf{x}}^{0} WATER}$. The latter, individual, is rather close to $\forall$ from the point of view of extension constraining. It is not difficult to extend the DP-determiners by allowing complex relations constraining objects in the extension of nominals. For instance, the determiner $\mathbf{D}_c = \big(\mathbf{H} \Downarrow_{\mathsf{x}}^{\omega} \big(\mathbf{H} \Downarrow_{\mathsf{y}}^{\omega} \text{ROSE}, \mathbf{H} \Downarrow_{\mathsf{z}}^{\omega} \text{LILIES}\big) (\mathbf{card}(\mathsf{y}) > \mathbf{card}(\mathsf{z}))\big)$ will be used in the $\mathrm{O}|\mathbf{P}$-subplan $\mathbf{D}_c \mathcal{A}_\cup \{\Uparrow_{\mathsf{y}}, \Uparrow_{\mathsf{z}}\}$ of *At least three girls gave* $(\textit{more roses than lilies})_{\mathbf{D}_c}$ *to John*. Such determiners are in practice comparable with so called cumulative quantifiers generally treated using generalized quantifiers (cf. [10, 11]). In our example, $\mathcal{A}_\cup \{\Uparrow_{\mathsf{y}}, \Uparrow_{\mathsf{z}}\}$ is a nominal aggregate with union extension: $\left|\mathcal{A}_\cup \{o_1, o_2\}\right|^\Sigma = |o_1|^\Sigma \cup |o_2|^\Sigma$. In the end, due to the "quantifier-freeness", the static DP semantics is fully compositional (DP-determiners are interpreted *in situ*, i.e. in verbals' argument positions).

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