

ANOTHER LOOK AT NOMINAL COMPOUNDS

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ABSTRACT

We present a progress report on our research on nominal compounds (NC's). Recent approaches to this problem in linguistics and natural language processing (NLP) are reviewed and criticized. We argue that the notion of "role nominal", which is at the interface of linguistic and extralinguistic knowledge, is crucial for characterizing NC's as well as other linguistic phenomena. We examine a number of constraints on the semantic interpretation rules for NC's. Proposals are made that should improve the capability of NLP systems to deal with NC's.

I INTRODUCTION

A. Problem Statement

As a first approximation, we define a nominal compound (NC) as a string of two or more nouns having the same distribution as a single noun, as in example (1):

(1) aircraft bomb bay door actuating cylinders

We will see below that provisions have to be made in some cases for intervening adjectives.

NC's can exhibit various degrees of lexicalization, but we will focus our attention on productive rules for forming novel compounds. As to their surface syntax, NC's can assume any structure generated by the rule $N \rightarrow N N$; accordingly, their structural ambiguity grows exponentially with their length (following the "Catalan sequence"). How, then, do we determine that the normal interpretation for (1) imposes the bracketing shown in (2), rather than any of the other 41 syntactically possible bracketings?

(2) ((aircraft ((bomb bay) door))
(actuating cylinder))

B. Goals of the study

We believe that the analysis of NC's represents an important and largely unsolved problem. From a theoretical point of view this problem raises the question of how to deal with noun

semantics. And since noun meaning appears to be closely connected with knowledge of the world, one is led to explore the modes of interaction between linguistic and conceptual knowledge.

From an NLP perspective, NC's have turned out to be an important stumbling block for systems that attempt to deal with real-life text, especially in technical domains, for purposes such as machine translation (Isabelle, to appear), information retrieval, etc.

Our ultimate goal is to develop an NLP system capable of analyzing large classes of NC's in the sublanguage (Kittredge and Lehrberger, 1982) of aircraft maintenance manuals. We do not aim at solving all cases, since we believe the problem to be exceedingly difficult. At the present stage of our inquiry, we concentrate on the design of a suitable theoretical framework.

In section II, we present a brief review of previous work in linguistics and NLP. In sections III and IV, we examine two aspects of the semantics of nouns that are crucially relevant to the analysis of NC's: predicative nouns and role nominals. Finally, in section V, we explore possible constraints on the semantic interpretation of NC's.

II BACKGROUND

A. Approaches in Linguistics

The early study of Lees (1963) classified NC's on purely grammatical criteria, and it failed to provide constraints that could explain how NC's are semantically interpreted.

In a number of more recent studies, such as Levi (1978), there has been an attempt to view NC's as governed by tight semantic constraints. Thus, according to Levi, any novel NC realizes a pattern where either: a) the head noun is a deverbal nominalization and its modifier is interpreted as an argument of the related verb; or b) the two nouns are related by one of exactly nine deletable predicates ("is the cause of", "is for", etc.).

This reductionist attempt has been criticized, most notably by Downing (1977), on the

grounds that the interpretation of NC's crucially involves pragmatic knowledge, and that numerous cases of NC's (such as thalidomide parents) will resist any analysis in terms of a closed set of relations. These criticisms have led theorists like Selkirk (1982) to adopt the position that only "verbal compounds" (those constructed on a pattern "argument + nominalization") are amenable to linguistic characterization; all other NC's would have to be explained in separate extralinguistic theories.

C. Approaches in NLP

Several systems have been developed in an NLP framework to deal with the problem of interpreting NC's; two recent examples are reported in Finin (1980) and McDonald (1982).

In both systems, the individual nouns of an NC are first mapped onto conceptual representations where concepts are characterized by a set of "roles" or "slots", and are arranged in an abstraction hierarchy. Interpreting a compound then amounts to forming a derived concept on the basis of the constituent concepts; in most cases, this is done by interpreting one of the concepts as a slot filler for the other. For example, the interpretation of steel adapter would involve inserting the concept associated with steel into a RAW-MATERIAL slot within the representation of adapter. But the authors do not examine in any detail the question of eventual constraints on this interpretation process, such as the effect of word order.

Another crucial issue which has not been explored in sufficient detail, is the nature of, and the justification for the particular set of slots which is assigned to a given concept. Finin is somewhat more explicit on this question. Some nouns have slots which represent standard case roles. Role nominale, on the other hand, are nouns which refer to a particular case role of another concept; for example, food refers to the object role of eat, and this fact provides the key to the interpretation of cat food. This notion will be examined in detail below. But Finin also resorts to other types of slots (e.g. "raw-material") which are not discussed.

III PREDICATIVE NOUNS

A. Root Nouns with Arguments

The fact that several classes of non-derived nouns strictly subcategorize phrases which are semantically interpreted as arguments has received very little attention in the literature. This phenomenon would deserve an extensive study, and we can only give here some relevant examples, together with an indication of the semantic categories between which the relation expressed by the noun effects a mapping:

- (3) a. measure nouns
map: objects onto quantities
examples: speed (of), temperature (of), volume (of), size (of)
- b. "area" nouns
map: objects onto subparts
examples: top (of), side (of), bottom (of), center (of), core (of)
- c. collective nouns
map: individuals onto sets
examples: group (of), set (of)
- d. representational nouns
map: objects onto representations of objects
examples: picture (of), diagram (of), sense (of)
- e. other examples
location (of), goal (of), brother (of), king (of)

Most if not all of these argument-taking nouns can have their argument satisfied by a modifier noun in an NC:

- (4) a. oil temperature
- b. box top
- c. tank group
- d. circuit diagram
- e. component location

A treatment in terms of predicate/argument patterns for this type of NC seems far superior to Levi's (1978) use of the semantically empty "deletable predicate" HAVE ("the component HAS a location"). Although these NC's are excluded from Selkirk's (1982) class of verbal compounds, they are amenable to the same type of semantic description.

B. Action and State Nominalizations

Most studies on NC's have recognized the fact that deverbal nominalizations exhibit a semantic behavior closely related to that of the verb, and subcategorize elements that can occur as modifier nouns in NC's. As mentioned above, these are in fact the only cases that Selkirk (1982) deems characterizable at the level of linguistic competence.

But there seems to be no reason why deadjectival nominalizations should be handled in a different way. In examples (5) and (6), an action and a state are nominalized, with the argument occurring either in a prepositional phrase or as a modifier in an NC:

- (5) a. Someone removes the pump.
b. removal of the pump
c. pump removal
- (6) a. Uranium is scarce.
b. scarcity of uranium
c. uranium scarcity

We are not claiming that there is exact synonymy between the (b) and (c) examples, but only that they exhibit the same predicate/argument pattern. Action nominals can take various types of arguments in NC's, and sometimes several of them simultaneously:

- (7) a. pump failure (subject)
- b. Montreal flight (source, goal)
- (8) a. poppet chatter tendency

IV ROLE NOMINALS

A. Nominalizations

Deverbal nominalizations can refer not only to the action expressed by the verb, but also to the agent (driver), instrument (lubricant), patient (employee) and result (assembly) of this action. Except maybe for results, the term "role nominal" seems appropriate, since the nominalization refers to the filler of one of the roles of the verb. Although these nouns are not, strictly speaking, predicative, they generally permit to form NC's in which the other is interpreted as an argument of the underlying verb:

- (9) truck driver
= one who drives trucks
- (10) engine lubricant
= something with which engines are lubricated
- (11) IBM employee
= one who is employed by IBM
- (12) pump assembly
= the result of assembling a pump

With agent and instrument nominals (9, 10), there is a strong tendency to assign an "habitual" aspect to the underlying verb and generic reference to its object; this kind of interpretation is awkward when the argument appears in a PP:

- (13) ?a driver of trucks

B. Root Nouns

The term "role nominal" is due to Finin (1980) who uses it to cover not only nominalizations of the type described above, but also any noun which can be semantically interpreted as referring to a role of a given verb, whether or not this verb happens to be morphologically related. This claim amounts to saying that, semantically, we have relations such as the following:

- (14) a. pilot:fly :: driver:drive
- b. gun:shoot :: lubricant:lubricate
- c. food:eat :: employee:employ

A related claim underlies Zhokhovskij & Mel'cuk's (1971) use of certain "lexical functions":

- (15) a. $S_1(\text{buy})$ = buyer
- b. $S_1^3(\text{buy})$ = seller
- c. $S_{\text{loc}}(\text{battle})$ = battlefield
- d. $S_{\text{inst}}(\text{see})$ = eyes

where S_i , S_{loc} and S_{inst} are defined as functions that yield the typical name of, respectively, the i^{th} actant, the location and the instrument.

Fillmore (1971) also makes a comparable proposal, when he suggests that the lexical entry of knife should include (16) as a component:

- (16) use: I of <V O I A>
 where V=cut

C. On the Definition of Role Nominals

How exactly should we understand the notion of role nominals? Finin's statement that they refer to an underlying case role of a verb is not accurate: they refer to role fillers, not to the roles themselves. Assuming that they denote a set of role fillers, we can ask if this set is:

- a. the set of all possible fillers for the role; or
- b. a set of typical fillers for that role; or
- c. any set of possible fillers for the role.

Possibility (a) seems to describe correctly numerous cases of deverbal nouns. For example, it seems clear that anyone who is employed is an employee. However, with agents and instruments, there is a tendency to reserve the role nominal for habitual fillers: one hesitates to apply the term writer to a person who only wrote a letter. Moreover, with this definition, knife would not be a role nominal for cut, since it is perfectly possible to cut bread with a sword. The notion would then lose much of its power, since we need it to explain why bread knife is interpreted as "a knife used as an instrument for cutting bread".

On the other hand, definition (c) seems too weak: even if a sword can be used to cut bread, bread sword is odd in a normal context (contextual factors will be discussed below). Thus, definition (b) seems the most appropriate.

D. Justifying Role Assignments

For those role nominals where there is no morphological evidence of relatedness with the underlying verb, one is forced to rely mostly on intuitions. However, the risk of arbitrariness can be reduced by looking for further evidence from other linguistic phenomena.

1. Evaluative Adjectives

When Fillmore (1971) introduced his notion of role nominal, he was attempting to characterize the behavior of evaluative adjectives, not the behavior of NC's. He noted that a good X, where X is a role nominal, means:

- a. if X is an agent: one who performs the associated activity skilfully
(a good driver, a good pianist);
- b. if X is an instrument: a thing which permits the associated activity to be performed easily
(a good knife, a good broom);
- c. In other cases, it seems that the resultant meaning is less predictable
(good food has certain properties concerning nutritiousness and taste; a good house is comfortable, built to last, etc.).

As far as we can tell, the evaluation domain for agents and instruments is precisely the activity which is relevant for the understanding of NC's. Thus while good driver evaluates the driving, car driver specifies its object; moreover, in good car driver, car falls within the evaluation domain: car drivers and truck drivers are evaluated on different scales. Evaluative adjectives can thus be used as a further source of evidence in the description of role nominals.

2. Denominal Verbs

Another phenomenon which is relevant to the question of role nominals and NC's is the creation of denominal verbs. Clark & Clark (1979) examine this very productive process, in which a verb formed by zero-affixation is understood "in such a way that the parent noun denotes one role in the situation, and the remaining surface arguments of the denominal verb denote other roles in the situation" (p. 787). For example, Max swayed downtown means that Max went downtown on a subway. Intuitively, it appears obvious that the knowledge involved in this interpretation process is very closely related to whatever permits interpreting the NC downtown subway as "the subway that goes downtown".

An important aspect of C & C's work is to show that the formation of denominal verbs is heavily dependent on contextual knowledge. Thus if you and me both know that Phil has long had the crazy habit of sticking trombones into the nose of bypassers, I can inform you that Phil has just tromboned a police officer. Notice that in the same context, good trombone would presumably mean a trombone that is easy to stick into someone's nose.

In such cases, the interpretation is based on particular, situational knowledge. NC's can also be based on this type of knowledge. For

example, if that same Phil uses different types of trombones for men and women, we might speak of his women trombones, to mean trombones of the type that Phil sticks into the nose of female bypassers.

But C & C claim that, more frequently, denominal verbs are based on generic knowledge about concrete objects, knowledge which is accessible to all speakers in a linguistic community. This claim is to be linked with Downing's (1977) remark that although NC's are sometimes "deictic", they are most often based on generic or permanent relationships.

Obviously, the relevant knowledge (whether particular or generic) is at least as much about the world as about language. In fact, it is clear that both types condition each other. For example, objects that are used as vehicles will tend to be verbalized on the syntactic pattern of movement verbs; and in the absence of other evidence, one is likely to infer from its syntax that The fairy pumpkined the kids to Narnia alludes not to an "eating pumpkin" but to a "transportation pumpkin".

In order to predict the range of meaning of large classes of denominal verbs, C & C propose to encode some generic knowledge in the lexicon, by means of "predominant features" such as:

- (17) a. x is the agent of Act (to pilot y)
- b. x is the instrument of Act (to pump y)
- c. x is the result of Act (to group y)
- d. x is the location of y (to can y)
- e. x is the locatum of y (to cover y)
- f. x is the time of Act (to weekend in y)

It is quite apparent that these features are meant to capture the same type of facts as role nominals. It is easy to find NC's which parallel each class of verb singled out by them:

- (17') a. aircraft pilot
- b. oil pump
- c. tank group
- d. oil can
- e. pump cover
- f. Montreal weekend

We believe that the semantic mechanisms that are at work in the interpretation of NC's, denominal verbs and evaluative adjectives are basically similar. By using independent evidence from these phenomena, and an adequate generalization of the notion of role nominal, one can go a long way toward uncovering the relevant semantic mechanisms.

The notion of role nominal, as we understand it, is at the interface between linguistic and extralinguistic knowledge. Nouns may have several different roles, depending on the contingencies of the entities that they denote; in those cases context usually makes one role more salient. In fact, context may even impart a noun with an unusual role, as we have seen. However, we believe that in ordinary texts, such as technical

manuals, NC's that are analyzable in terms of role nominals are most often based on the usual, generic roles of the nouns. But this can only be shown through a large scale description of the relevant NC's.

E. A Tentative Scheme

Since the knowledge we have to encode is tied to world knowledge, there is a risk that it could become overwhelmingly complex. However, we will minimize this risk, by limiting the scope of our inquiry to a suitably restricted sublanguage. Technical manuals are interesting in this respect because they exhibit at the same time a tightly constrained universe of interpretation, and an exceptional productivity in compounding.

As to the semantic framework, we will not use case grammar, even if our discussion of role nominals was couched in the terms of this theory for expository purposes. As is well-known, case grammars raise a number of difficult problems.

For example, the distinction between agent and instruments is problematic. At the morphological level, both can give rise to -er nominalizations; at the syntactic level, both can appear in subject position, and in with NP environments (cf. co-agents); and at the semantic level, both notions are frequently undistinguishable, especially in texts dealing with machines, such as technical manuals. Since action verbs can generally occur with an agent, an instrument, or both, it does not seem necessary to include two slots for each verb in the dictionary: general rules should predict the relevant facts.

Another problem is that if we want the notion of role nominal to be general enough, a role nominal should be able to refer to entities which are not case slots, at least in the usual sense of this term. Result nominals, for instance, do not refer to a case slot as such.

There is in fact no evidence that the interpretation rules for NC's crucially involve case roles rather than argument places, and our descriptions will be couched in terms of a predicate/argument notation. This notation is perfectly compatible with the use of an ontology that is richer than standard predicate logic.

For example, if we agree with Jackendoff's (1983) claim that "place" and "paths" constitute basic cognitive categories, we can define "typed" variables with the appropriate range. In our descriptions below, *p* will denote a path variable, that is, a variable ranging over entities denoted by complex expressions constructed out of "path functions" (*into*, *from*, *toward*, *via*, etc.) and "places". Similarly, we will use *e* as an "event" variable, as in Moore (1981) and Hobbs (1984).

A role nominal will contain within its lexical entry one or more statements of the form "x

such that P(x)". We do not think that diacritic markers such as "typical function" are required; rather, notions such as typicality, should be a consequence of the semantic rules which interpret lexical entries.

We give below a few examples of the type of lexical specification for role nominals with which we want to experiment. At this stage of our work this should be taken as nothing more than a first approximation. The material enclosed in brackets represents selectional restrictions.

- (18) pilot
 - x such that FLY(x,y,p)
<aircraft(y)>
- (19) adapter
 - x such that ADAPT(x,y,z)
(this entry is produced by derivational morphology)
- (20) tank
 - x such that CONTAIN(x,y)
<fluid(y)>
(container, chamber, reservoir, bay, compartment, etc. are similar but selection restrictions can differ)
- (21) hinge
 - x such that ATTACH(x,y,z)
- (22) brace
 - x such that SUPPORT(x,y)
- (23) witness
 - x such that SEE(x,e)
- (24) line
 - x such that CONDUCT(x,y,p)
<fluid(y)>

IV CONSTRAINING INTERPRETATION RULES

The preceding sections have discussed two aspects of the lexical semantics of nouns that are relevant for the analysis of NC's: argument-taking nouns and role nominals. Assuming that the lexicon contains this type of information, we can now ask how it is used by semantic interpretation rules.

More specifically, the picture that emerges is that lexical entries provide predicate/argument patterns which contain variables; these variables have to be bound to the semantic material associated with some other noun. We must then ask what are the rules that govern this binding process.

A. Relative Order of the two Nouns

1. Predicative Nouns

Selkirk (1982) claims that the modifier noun can satisfy an argument of the headnoun but not vice-versa. Finin (1980) claims that argument satisfaction (or slot filling) is possible in both directions. Finally, McDonald (1982) takes the intermediate position that satisfaction of the head by a modifier is much more frequent.

Now, consider the following pairs of examples:

- (25) a. oil temperature
- b. ??temperature oil
- (26) a. uranium scarcity
- b. ??scarcity uranium
- (27) a. pump removal
- b. ??removal pump
- (28) a. student invention
- b. ??invention student

It is clear that the (b) examples, if interpretable at all, cannot easily realize the pattern found in the (a) examples. However, there is a very productive process which permits an action nominal to occur to the left of its argument; this pattern is most productive with inanimate headnouns:

- (29) a. repair man
- b. ?man repair
- (30) a. cooling device
- b. device cooling
- (31) a. bleed valve
- b. ??valve bleed
- c. valve bleeding
- (32) a. jacking point
- b. ??point jacking

In the first three (a) examples, the headnoun is interpreted as a subject argument (agent or instrument). In (28a), point is interpreted as a location (where one jacks something). In all of the (a) examples, the action nominal is interpreted as denoting a permanent role or function of the headnoun.

When order is reversed, meaning and, eventually, acceptability are affected. In the (b) examples, the action nominal is not interpreted as expressing a permanent function of the other noun. Thus, if one can manage subject interpretations in (29b) and (31c) -- "a repair done by men (not robots)" and "a valve which bleeds something" --, it will not follow that the men are repair men or that the valve is a bleed valve.

The pattern "argument + predicative noun" has some peculiarities of its own; for example, why is (32b) unacceptable no matter the role assignment that one makes? Or why is girl swim-

ming unacceptable? In the latter case, it cannot be, as suggested by Selkirk (1982) that subject arguments are prohibited in general: pump failure is fine. It may be that subjects are ruled out for -ing nominals, unless they express a result (cf. consumer spending).

But on the whole, the pattern where the predicate comes first is much more constrained, since it permits only action nominals, and produces a semantic result very similar to role nominals. Thus, a cooling device and cooler denote very similar entities; the same is true of jacking system and jack. Notice that in examples such as:

- (33) air temperature monitoring system

monitoring system forms a constituent, even if air temperature is understood as the object of the monitoring; this is confirmed by the fact that (34) receives a similar interpretation:

- (34) monitoring system for air temperature

It seems that this modification pattern has the effect of creating a role nominal out of its two constituents.

2. Role Nominals

Here again, the order of the nouns strongly conditions the resulting interpretation:

- (35) a. truck driver
- b. ??driver truck
- (36) a. oil pump
- b. pump oil
- (37) a. pump case
- b. ?case pump
- (38) a. equipment bay
- b. bay equipment

In the (a) examples, the modifier noun is interpreted as the object of the underlying verb (drive, transfer, detect, hold); here too, a permanent connection is established. A truck driver is a person whose (social) function is to drive trucks, and that person is still a truck driver when he/she drives a scooter. If you use an oil pump to pump your tomato juice, it still qualifies to be called an oil pump.

But when the nouns are inverted, there is a change in meaning and, possibly, in acceptability. It is hard to find a sensible interpretation for driver truck. The most natural interpretation for pump oil is "oil used for lubricating pumps": in this case, oil has become the relevant role nominal. There is also a possibility for an interpretation such as "oil in the pump" or "oil coming from the pump". We are not sure how that type of interpretation should be produced. But it seems clear that oil can only become an actor in

a permanent function of the pump when pump is the headnoun.

It is easy to see that the other examples exhibit a similar behavior. We therefore conclude that role nominals tend to establish permanent, functional connections with their modifiers only. When they modify a headnoun, either this noun will absorb them itself (if it is a predicative or role nominal) or else a looser connection such as a locative one will be created.

B. Multiple Modification

1. Argument Ordering

When a predicative noun or role nominal in head position is modified by more than one argument, it seems that ordering (39) will apply, as illustrated in the examples below:

(39) time < paths < subject < object
loc

(40) a. computer fuel testing
b. ??fuel computer testing

(41) a. Montreal jet flights
b. ??jet Montreal flights

(42) a. evening Montreal trains
b. ??Montreal evening trains

2. A Broader Perspective

So far, we have concentrated on predicative nouns and role nominals, thereby excluding various types of compounds. When we look at the broader picture, different problems are raised. First, (in technical manuals) we find examples with intervening adjectives as in (43):

(43) (Remove) front cockpit right shelf aft control panel.

While the formation of NC's such as those we have examined in previous sections is usually considered to be a lexical process, there is some evidence that, in examples like (43), syntactic processes are at work. Notice that each one of the three main groups in (43) is referential: "the (...) panel of the (...) shelf of the (...) cockpit", much as if there was an implicit genitive marker. But genuine compounds (that is, those of syntactic category N) are usually considered to be anaphoric islands (Levi, 1978). One possible explanation is that (43) should in fact be analyzed as containing three NP's.

A comparison of the following examples provides some support for that view:

(44) a. Remove front cockpit right shelf.
b. Remove right cockpit shelf.

In (44a), cockpit has definite reference and is

interpreted as no more than a location for the shelf. However, in (44b), when the scope of right includes shelf, cockpit becomes nonreferential; cockpit shelf then denotes a type of shelf. These facts seem to indicate that this scoping of right, in virtue of syntactic constraints, forces one to take cockpit shelf as something of category N; and when we do so, shelf becomes a role nominal whose argument receives the type of "permanent function" interpretation discussed above.

Core NC's, those which establish argument connections with a predicative noun or role nominal, appear to form a tightly bound unit:

- (45) a. ??oil high temperature
b. ??truck good driver
c. ??equipment left bay

Some adjectives, the "nonpredicating" adjectives of Levi (1978) can appear within core NC's. But they are in fact nouns in disguise, and they receive an argument interpretation; in (46), it is understood that one repairs a structure.

- (46) aircraft structural repairs

Thus, if we are willing to make a distinction between syntactic compounding (similar to genitive phrases) and core NC's, it can be claimed that true compounds form anaphoric islands and cannot be separated by adjectives.

Finally, there are certain types of nominal modifiers (for which we have as yet no analysis to offer) whose degree of cohesion with the headnoun is somehow intermediate between nouns interpreted as arguments and nouns in separate (pseudo-genitive) NP's. For example, nouns which stand in a "material of" relation to the head cannot precede adjectives, but must precede arguments:

- (43) a. large steel tank
b. ??steel large tank

- (44) a. steel fuel tank
b. ??fuel steel tank

The constraints that we have seen, and no doubt others yet to be discovered, are certainly significant from a theoretical point of view; but they also have practical value for NLP systems which have to deal with NC's.

VI CONCLUSIONS

We have discussed two classes of nouns that have particular importance in NC formation: predicative nouns and role nominals. We have shown that the latter class is also relevant to the description of evaluative adjectives and denominational verbs. A tentative framework for the description of role nominals has then been proposed. Finally, we have seen that rules which interpret

NC's obey a number of constraints. A distinction has been made between "pseudo-genitive" constructions and core NC's, the latter forming a tightly bound unit with internal ordering constraints.

Much work remains to be done on the issues that we have discussed here; it is likely that experimentation with actual descriptions on a larger scale will lead to several refinements and revisions. Moreover, as has been pointed out in the last section, our description still ignores a number of types of compounding, and further difficulties are to be expected. Nonetheless, we are confident that our work will, in the near future, result in a small NLP system capable of analyzing a broad range of NC's.

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