Identity Criteria of CNs: Quantification and Copredication*

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The term copredication refers to the phenomenon in which more than one predicate, representing a verb or an adjective and requiring different types of arguments, are used in coordination and applied to the 'same' CN argument. For instance, consider the following sentence,

(1) John picked up and mastered the book.

the predicates 'pick up' and 'master' require physical and informational objects as their arguments respectively, and apply in coordination to the argument 'the book', which is used in its physical sense with respect to 'picked up' and in its informational sense with respect to 'mastered'. When quantification is involved, as exemplified by the following example:

(2) John picked up and mastered three books.

the situation becomes more subtle and evolved because, in such more complex situations, proper semantic treatments seem to require that appropriate identity criteria for the CN be determined according to contextual information.

People have discussed how to deal with identity criteria involved in copredication including, for example, [1, 4, 5]. In particular, Gotham [5] gives a detailed analysis of the issue in a mereological framework. The current authors have also considered the issue in [2] where, however, the necessity of considering different identity criteria was not sufficiently recognised and hence an incorrect treatment was put forward. In this paper, we revisit this issue, following the suggestion in [7]: in general, we need to consider identity criteria explicitly; in other words, a CN is not just interpreted as a type, but also associated with an identity criterion (IC) over the type – formally, a setoid. This, we argue, gives us an adequate way of dealing with individuation, particularly when both quantification and copredication are involved.

Common Nouns as Setoids. The idea of CNs as types (rather than predicates) was first studied by Ranta [9] and further developed and elaborated by Luo and colleagues in a series of papers including [6, 7, 8, 3]. In particular, it has been proposed in [7] that the interpretation of a CN is not just a type, rather a type associated with an identity criterion for that CN. In other words, a common noun N is in general interpreted as a setoid – a pair $(A_N, =_N)$, where A_N is a type and $=_N$: $A_N \rightarrow A_N \rightarrow Prop$ is an equivalence relation over A_N.

As examples, human can be interpreted as type $Human$ with $=_h$ as its IC: formally, $[\![human]\!] = (Human, =_h)$. One can then define $[\![man]\!] = (Man, =_m)$, where Man may be defined as $\Sigma x{:}Human.male(x)$ with $male : Human \rightarrow Prop$. What is then $=_m$, the IC for men? In such a simple case, the identity criterion for men is *inherited* from that for humans:

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two men are the same if, and only if, they are the same as humans. Formally, for $m_1, m_2 : Man$, $m_1 =_m m_2$ is defined as $\pi_1(m_1) =_h \pi_1(m_2)$, where π_1 is the first projection.[1]

In more sophisticated cases involving quantification, copredication or both, one cannot rely on the simple inheritance of identity criteria: this will be explicated below, where we use 'three' as an example to explain proper semantic interpretations of sentences like (2). Furthermore, it is worth noting that, in general, two CNs may be interpreted as $(A, =_1)$ and $(A, =_2)$ with the ICs different – these two CNs are different CNs.

Quantifications and Copredication. For a common noun $N = (A_N, =_N)$ and a verb/adjective whose interpretation is the predicate $P : A_N \to Prop$,[2] the semantics of 'three' is given in (3):

(3) $Three(N, P) = \exists x, y, z : A_N.\ D[N](x, y, z)\ \&\ P(x)\&P(y)\&P(z)$,

where $D[N](x, y, z) = (x \neq_N y)\ \&\ (y \neq_N z)\ \&\ (x \neq_N z)$, meaning that x, y and z are distinct w.r.t. the IC for N. As an example, assume that 'physical book' is interpreted as $(Book, =_p)$ where $Book \leq (\text{PHY} \bullet \text{INFO}) \leq \text{PHY}$ (see [6, 8] for detailed and formal treatments of dot-types) and $=_p$ is the identity criterion between physical objects. Then, the semantics of (4) is given as (5), where $[\![pickup]\!] : Human \to \text{PHY} \to Prop \leq Human \to Book \to Prop$:

(4) John picked up three physical books.

(5) $Three([\![physical\ book]\!], [\![pickup]\!](j))$

When copredication is involved in a sentence such as (2), a proper treatment of quantification becomes more involved. Let $N = (A_N, =_N)$, $N_1 = (A_{N_1}, =_{N_1})$ and $N_2 = (A_{N_2}, =_{N_2})$ be CNs, and $A_N \leq A_{N_1} \bullet A_{N_2}$. Then the quantifier 'three' can be defined as (6), where $P : A_{N_1} \bullet A_{N_2} \to Prop$, and the sentence (2), repeated here as (7), can be interpreted as (8), where because of contravariance of subtyping, $[\![pickup]\!]$ and $[\![master]\!]$ are both of type $Human \to (\text{PHY} \bullet \text{INFO}) \to Prop$ (and therefore so is $[\![pickup\ and\ master]\!]$):

(6) $Three^{\bullet}(N, N_1, N_2, P) = \exists x, y, z{:}A_N.\ D[N_1](x, y, z)\ \&\ D[N_2](x, y, z)\ \&\ P(x)\&P(y)\&P(z)$, where $D[N_1](x, y, z) = (x \neq_{N_1} y)\&(y \neq_{N_1} z)\&(x \neq_{N_1} z)$ and similarly for $D[N_2](x, y, z)$.

(7) John picked up and mastered three books.

(8) $Three^{\bullet}([\![book]\!], \text{PHY}, \text{INFO}, [\![pickup\ and\ master]\!](j))$

Remarks on determining ICs. Using the above definitions for quantifiers, one can similarly consider more elaborate examples like *John mastered three heavy books* and *John picked up three informative books*, or even those multiple adjectives like *John picked up/mastered an informative heavy book*. In particular, when copredication is involved, one of the interesting issues is to consider which identity criterion to use and how to determine it. Consider the following sentences:

(9) Fred picked up three heavy books.

(10) Fred mastered three heavy books.

[1]Most of the cases are such simple ones, where a subtype just 'inherits' the IC of the super type. That is why we usually just say 'CNs as types' since the ICs are not important. However, in more sophisticated cases, ICs do not simply get inherited, as explained in this paper. Also, such an inheritance of ICs in simple cases is explained in more details in [7], where it is argued that in type theories proof irrelevance would be needed for this.

[2]When CNs are interpreted as setoids, the interpretations of verbs/adjectives should be *IC-respecting* predicates: for example, for $[\![talk]\!] : Human \to Prop$, $[\![talk]\!](h_1) \Leftrightarrow [\![talk]\!](h2)$ if $h_1 =_h h_2$.

(11) Those three lunches were delicious but took forever.

First, it seems to be the case that it is the verb (or adjective) that determines which IC to be used in order for proper semantics to be given: for instance, it is the IC between physical objects to be used for (9) while the IC between informational objects for (10). Furthermore, when copredication is involved, it seems that we should use *both* ICs: for instance, (11) has the following semantic interpretation (12), where $Three^{\bullet}$ is defined in (6):

(12) $Three^{\bullet}([\![lunch]\!], Food, Event, [\![delicious]\!]\ \&\ [\![take\ forever]\!])$.

which uses both ICs (IC for foods and IC for events): when it is expanded, we obtain (13) where the use of both ICs becomes explicit (they are used in the inequalities in formulae $D[...](x, y, z)$):

(13) $\exists x, y, z{:}Lunch.\ D[food](x, y, z)\ \&\ D[event](x, y, z)\ \&\ [\![delicious]\!](x/y/z)\ \&\ [\![take\ forever]\!](x/y/z)$,

where $P(x/y/z)$ stands for $P(x) \& P(y) \& P(z)$.

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