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Dynamic Social Choice for Pronominal Reference

Sumiyo Nishiguchi
Department of Liberal Arts, Faculty of Science Division I, Tokyo University of Science

Pronouns are known for their referential ambiguities. In (1), *she* has multiple candidates for its antecedent—Emma, Lisa and Lisa's mom. Proximity and saliency of antecedents have been considered to be key factors to decide (Leass 1991). In (1), the most proximate antecedent *her (Lisa)'s mom* is identified to be the antecedent for *she*.

(1) Frances: ...Not while Emma's not here. You know Emma
Billy: Mm.
Frances: she's, she was walking with Lisa and I weren't there and her Mum sh– jus– , like *she* muc– , *she* mucks about a lot and she told Leigh that if he don't serve her he's gonna die, she's gonna punch him right! Cos she's quite big, you know.... (BNC KSW435-441)

However, proximity does not always resolve referential ambiguity of pronouns. *Him* in (2a) unambiguously means someone other than the closest *John*—some discourse-salient entity, as indicated by the indices. When *he* is embedded under the matrix clause as in (2b), the pronoun becomes ambiguous between *John* and someone else salient in the discourse.

(2) a. John$_i$ likes him$_{\{*i/j\neq i\}}$.

b. John$_i$ said he$_{\{i/j\}}$ likes himself$_{\{i/j\}}$.

Although Condition B in linguistic binding theory (Chomsky 1981, Reinhart 1983) says *pronouns must be free in their local domain*, (3) is ambiguous in four ways and can have either one of the following interpretations: (i) John broke John's leg, (ii) John broke Bill's leg, (iii) Bill broke Bill's leg, or (iv) Bill broke John's leg.

(3) Anna: Bill$_j$ is a good goalkeeper.
Kim: John$_i$ said he$_{i/j}$ broke his$_{i/j}$ leg recently.

Although Social Choice Theory (Arrow 1963, Moulin 1988, Taylor 2005, Gaertner 2009) has not yet been studied from linguistic perspective, being only briefly mentioned in van Rooij (2011) in relation with interadjective comparison, I claim that Arrow's Impossibility Theorem is obeyed in a social choice of pronominal reference.

Since the referents of pronouns can be ambiguous, pronoun resolution can be compared with voting by multiple voters—in this case, discourse participants. The candidates or choices would be different interpretation of the sentence. Identifying the antecedent of pronouns is a social choice and Social Welfare Function (SWF) decides the antecedent. In (4), the referent of *he* is ambiguous between *John*, the binder, and some other discourse referent. Suppose that the speaker meant the referent of *he* to be *Bob* who appeared in their previous discourse, while the hearer interpreted *him* to be *John*.

(4) Chris: John said he broke his leg.
Naomi: Did he? John looked fine when I saw him this morning.
Chris: It is Bob who broke his leg.
Naomi: I thought you were talking about John.

(5) a. Individuals I = {c, n}

b. Candidates χ = {j, b}

c. Ordering $\mathrm{jR}_c\mathrm{b} \wedge \mathrm{bR}_n\mathrm{j}$

d. Denote the set of linear orders on χ by $L(\chi)$. Preferences (or ballots) are taken to be elements of $L(\chi)$.

e. A profile R = (R_c, R_n) $\in L(\chi)^{|I|}$ is a vector of preferences

f. A social choice function (SCF) or voting rule is a function $\mathrm{F} : L(\chi)^{|I|} \to 2^{\chi} \setminus \{\emptyset\}$ mapping any given profile to a nonempty set of winners.

g. A social welfare function (SWF) is a function $\mathrm{F} : L(\chi)^{|I|} \to L(\chi)$ mapping any given profile to a (single) collective preference order.

There are three possible antecedents for *she* in (1)—Emma, Lisa and Lisa's mother. Let us say that Billy (b) prefers Emma (e) to Lisa (l), and also Lisa to Lisa's mother (m) to be the antecedent. On the other hand, the speaker Francis (f) prefers Lisa's mother to the other two, Lisa's mother to Lisa, and Lisa to Emma according to the proximity. All three candidates are connected in accordance with Axiom 1, for all x and y, either xRy or yRx.

(6) a. $\mathrm{eR}_b\mathrm{l} \wedge \mathrm{lR}_b\mathrm{m}$

b. $\mathrm{mR}_f\mathrm{l} \wedge \mathrm{lR}_f\mathrm{e}$

Transitivity also holds for pronoun antecedent preferences. (6a) and (6b) each implies (7a) and (7b).

(7) a. $\mathrm{eR}_b\mathrm{lR}_b\mathrm{m}$

b. $\mathrm{mR}_f\mathrm{lR}_f\mathrm{e}$

SWF for pronoun resolution does not meet Pareto condition. The interpretation of the addresses may contradict with the one of the speaker. The preference ordering between Chris and Naomi is the opposite. Since the social decision jPb ignores Naomi's preference, the social welfare function is not Pareto.

(8) a. Chris: Bob is a good skier. But John said he broke his leg.
Naomi: Did he? Poor Bob!
Chris: No. I mean John broke his leg.

b. $\mathrm{jP}_c\mathrm{b} \wedge \mathrm{bP}_n\mathrm{j} \to \mathrm{jPb}$

A SWF *F* satisfies Independence of irrelevant alternatives (IIA) if the relative social ranking of two alternatives only depends on their relative individual rankings. Suppose the dialogue in (6) is modified into (9). The preference relations are denoted by R for (6) and R' for (9). The relative rankings between Bob and John remain unaffected by irrelevant candidate Victor's ranking.

(9) Chris: Victor is a good skier and so is Bob. But John said he broke his leg.
Naomi: Did he? Poor Bob!

(10) bR'$_c$v $\wedge$ vR'$_c$j $\wedge$ bR'$_n$j $\wedge$ jR'$_n$v
Then, $N^{R}_{b>j} = N^{R'}_{b>j}$ implies bF(R)j $\Leftrightarrow$ bF(R')j

Pronoun resolution is dominated, or dictated, by the speaker's meaning.

(11) xP$_c$y $\rightarrow$ xPy

The referent of each pronoun is determined by the assignment function g which returns an discourse entity, the referents, to indices indexed to pronouns.

(12) a. g = {<x, i>: x refers to i}

b. g = {<x, John>, <y, Mary>, <z, Steve>}

The space is given below:

(13) Information state σ consists of Social Welfare Function F, Social Choice Function C, individual's preferences R, variable assignment g, individuals in the discourse X, a set of indices such as i, a set of discourse participants V, and relation between decisions B.
Σ = < F, C, R, G, X, I, V, B>

The assignment function g assign John to the variable x, and is updated throughout the discourse.

(14) g(x) = John

(15) σ1 There were ooh's and aah's when he$_{x1}$ finished, and some unbridled laughter. Aileen$_a$ was looking dubiously at her$_{y1}$ husband$_h$ but he$_{x2}$ was in no mood to disapprove.

σ2 He$_{x3}$ winked at the Duke$_d$ and called across to him$_{x4}$, 'What a grand thing, your Honour, to have a wedding without a minister!' The Duke$_d$ did his$_{x5}$ stately bow at that and then Donald$_m$ was calling for another song.

σ3 Some of the veterans$_v$ were on the point of giving tongue but young Donald McCulloch$_m$ was on his$_{x6}$ feet and moving into the middle of the ring, he$_{x7}$ was full of himself$_{x8}$, sparkling with mischief but with an undertow of ardour.

σ4 'Duncan Ban MacIntyre$_b$ wrote a song for his$_{x9}$ wife Mary$_r$.

σ5 I do not know if Alex$_l$ used it to court his$_{10}$ $Mary_r$ – he$_{x11}$ must have used something – 'The joke was unconscious but crowing laughter came from the young men$_n$ beside the whisky jar.

(BNC A0N1311-1315, *King Cameron*)

(16) a. g1= {<y1, a>, <x2, h>}
I = {a, r} (a: author, r: reader)
S = {a, h}

b. g2 = {<x3, h>, <x4, d>}
S = {a, h, d, m}

c. g3 = { <x6, m>, <x7, m>, <x8, m>}
S = {a, h, d, v, m}

d. g4 = {<x9, b>}
S = {a, h, d, v, m, b, r}

e. g5 = {<x10, l>, <x11, l>}
S ={a, h, d, v, m, b, r, l, n}

f. $[\![her_y]\!]^{g1}$ = a

The variable assignment function g is regarded as a social choice function C. The set of best elements in S is called its choice set, and is denoted C(S, R) (Sen 1979).

Definition 1. *A variable assignment function g is a choice function C(S, R) over preference relations R and the whole set of alternatives X.*

R is a sequence of individual's preferences where R$_x$ is a preference ordering of x.

(17) a. R = (R$_a$, R$_r$)

b. g1: C(S, R) = {a, h}
g2: C(S, R) = {h, d}
g3: C(S, R) = {m}
g4: C(S, R) = {b}
g5: C(S, R) = {l}

(18) Author's dynamic preferences:
σ2: hR$_a$d for he_{x3} $\wedge$ dR$_a$h for he_{x4} $\wedge$ dR$_a$hI$_a$m for he_{x5} (aI$_x$b: x is indifferent between a and b, $\wedge$: dynamic conjunction)

(19) a. Social Decision:
hRd $\wedge$ dRh $\wedge$ dRhIm

b. (C(S1, R1)) B (C(S2, R2)) B (C(S3, R3))

c. B(C(S1, R1)) = C(S2, R2)

In comparison, Dynamic Predicate Logic (Groenendijk & Stokhof 1991) consider update semantics where two states differ with respect to variable assignment.

(20) h[x]g

The state g is updated with respect to the assignment to x. On the other hand, I consider an abstract function B between two assignment functions. The social choice in the previous state is the argument for the decision function to the next state.

Parkes & Procaccia (2013) model dynamic decision making under constantly changing preferences using Markov decision processes, in which the states coincide with preference profiles and a policy corresponds to a social choice function. My paper models a relation between the results of social choice function.