Filling gaps with Glue

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Problem Consider the simple example of gapping (Ross 1970) in (1) and its intended neo-Davidsonian (Davidson 1967, Castañeda 1967, Parsons 1990) representation in (2), where the constants m, l, h, and b refer to Marge, Lisa, Homer, and Bart, respectively. The representation in (2) reflects the fact that (1) refers to two seeing events, not just one. The first bracketed conjunct in (2) faithfully represents the first clause of (1) (i.e., *Marge saw Lisa*).

(1) Marge saw Lisa and Homer – Bart.

(2) $[\exists e.\, see(e) \wedge agent(e,m) \wedge theme(e,l)] \wedge [\exists e.\, see(e) \wedge agent(e,h) \wedge theme(e,b)]$

The challenge for any semantic theory of gapping is to – compositionally – obtain the second bracketed conjunct in (2) as the representation of the gapped clause in (1) (i.e., *Homer – Bart*), despite the missing verb.

A solution available within theories relying on empty constituents is that the gapped clause contains a covert verb with the right semantics – this could be an unpronounced copy of the overt verb in the first clause, or some generic phonetically empty verb anaphorically related to the overt verb. However, LFG eschews empty constituents unless there are good *syntactic* reasons to postulate them (Bresnan *et al.* 2016: §9.5). The aim of this paper is to provide an LFG+Glue (Dalrymple 1999, Asudeh 2022) analysis of simple gapping structures that does not assume empty constituents.

Solution Glue is resource-sensitive, so the semantic representation see introduced by the predicate *saw* in (1) must be used exactly once in the glue proof. The question is how to obtain the representation in (2), where see occurs twice.

A somewhat similar problem occurs when a dependent introduces a resource that is shared between conjoined predicates, as in (3)–(4). The semantic representation of *Bart*, i.e., b, occurs twice in (4). The standard solution in such cases is that the representation of the shared dependent, b, is an argument of the representation of the coordination *walked and whistled*, i.e., of $\lambda x.\, [\exists e.\, walk(e) \wedge agent(e,x)] \wedge [\exists e.\, whistle(e) \wedge agent(e,x)]$, resulting in (4).

(3) Bart walked and whistled.

(4) $[\exists e.\, walk(e) \wedge agent(e,b)] \wedge [\exists e.\, whistle(e) \wedge agent(e,b)]$

For a similar solution to work in gapping, the representation of the overt verb introduced in the first clause in (1) should be factored out and become an argument of the representation of the rest of the coordination, as schematically shown in (5):

(5) $[\lambda f.[\exists e.\, f(e) \wedge agent(e,m) \wedge theme(e,l)] \wedge [\exists e.\, f(e) \wedge agent(e,h) \wedge theme(e,b)]](see) \overset{\beta\text{-reduction}}{\rightsquigarrow}$ (2)

We flesh out this idea by building on Champollion's (2015) approach to event semantics and on Patejuk and Przepiórkowski's (2017) LFG analysis of the syntax of gapping.

Semantics Champollion (2015) argues that, instead of the usual existential closure at the level of the clause, the existential quantifier which binds the event should be introduced by the verb itself, as in (6).

(6) *saw* $\rightsquigarrow \lambda f.\, \exists e.\, see(e) \wedge f(e)$

Dependents are analysed as semantic modifiers, as in (7)–(8), combining with verbs as in (9)–(10).

(7) *Marge*$_{agent}$ $\rightsquigarrow \lambda V.\lambda f.\, V(\lambda e.\, agent(e,m) \wedge f(e))$ (8) *Lisa*$_{theme}$ $\rightsquigarrow \lambda V.\lambda f.\, V(\lambda e.\, theme(e,l) \wedge f(e))$

(9) *saw Lisa* $\rightsquigarrow$ [(8)]((6)) $\overset{\beta\text{-reduction}}{\rightsquigarrow} \lambda f.\, \exists e.\, see(e) \wedge theme(e,l) \wedge f(e)$

(10) *Marge saw Lisa* $\rightsquigarrow$ [(7)]((9)) $\overset{\beta\text{-reduction}}{\rightsquigarrow} \lambda f.\, \exists e.\, see(e) \wedge theme(e,l) \wedge agent(e,m) \wedge f(e)$

The final relevant ingredient of Champollion 2015 is the event closure in (11) (replacing the usual existential closure), leading to the final representation of the sentence *Marge saw Lisa* in (12), equivalent to the first bracketed conjunct in (2).

(11) [closure] $\rightsquigarrow \lambda e.\, true(e)$

(12) *Marge saw Lisa* (after closure) $\rightsquigarrow$ [(10)]((11)) $\overset{\beta\text{-reduction}}{\rightsquigarrow} \exists e.\, see(e) \wedge theme(e,l) \wedge agent(e,m) \wedge true(e)$

For this approach to work in the analysis of gapping, semantic representations of verbs such as (6) must be split:

(13) *saw* $\rightsquigarrow \lambda V.\, \lambda f.\, V(\lambda e.\, see(e) \wedge f(e))$

(14) $\lambda f.\, \exists e.\, f(e)$

We assume lexical verbs introduce two meaning constructors (MCs) corresponding to meaning representations in (13)–(14), while the gapped clause constructionally introduces a constructor corresponding to (14). In the case of the running example (1), when this MC combines with the agent Homer and the theme Bart, the representation of the gapped clause is (15):

(15) *Homer – Bart* (initial) $\rightsquigarrow \lambda f.\, \exists e.\, theme(e,b) \wedge agent(e,h) \wedge f(e)$

Similarly, (16) is the initial representation of the first clause, utilizing only the MC corresponding to (14) (without (13)).

(16) *Marge saw Lisa* (initial) $\rightsquigarrow \lambda f.\, \exists e.\, theme(e,l) \wedge agent(e,m) \wedge f(e)$

Assuming the standard approach to the semantics of coordination (Partee and Rooth 1983, Dalrymple *et al.* 2019: §16.7), conjoining (16) and (15) results in (17):

(17) *Marge saw Lisa and Homer – Bart* (initial) $\rightsquigarrow$
$\lambda f.\, [\exists e.\, theme(e,l) \wedge agent(e,m) \wedge f(e)] \wedge [\exists e.\, theme(e,b) \wedge agent(e,h) \wedge f(e)]$

Applying the representation of the verb in (13) to the representation of coordination in (17) results in (18):

(18) *Marge saw Lisa and Homer – Bart* (before closure) $\rightsquigarrow$ [(13)]((17)) $\overset{\beta\text{-reduction}}{\rightsquigarrow}$
$\lambda f.\, [\exists e.\, theme(e,l) \wedge agent(e,m) \wedge see(e) \wedge f(e)] \wedge [\exists e.\, theme(e,b) \wedge agent(e,h) \wedge see(e) \wedge f(e)]$

This derivation is slightly more complex than the schematic derivation in (5), because in (18) the representation of the verb is the functor rather than the argument. Applying (18) to the closure representation in (11) results in (19), which is equivalent to the desired representation (2) of the running example (1).

(19) *Marge saw Lisa and Homer – Bart* (after closure) $\rightsquigarrow$ [(18)]((11)) $\overset{\beta\text{-reduction}}{\rightsquigarrow}$
$[\exists e.\, theme(e,l) \wedge agent(e,m) \wedge see(e) \wedge true(e)] \wedge [\exists e.\, theme(e,b) \wedge agent(e,h) \wedge see(e) \wedge true(e)]$

Syntax–Semantics Interface For the syntax–semantics interface, this proposal relies on the analysis of gapping in Patejuk and Przepiórkowski 2017: (21) is the partial f-structure of the gapped clause in (1), while (20) is the partial f-structure of the first clause where dependents that are not shared are put in LOCAL (rather than in the main f-structure c).

(20) $$c\begin{bmatrix} \textsc{pred} & \text{‘}\textsc{see<subj, obj>}\text{’} \\ \textsc{local} & c^{1}\begin{bmatrix} \textsc{subj} & \begin{bmatrix} \textsc{pred} & \text{‘}\textsc{Marge}\text{’} \end{bmatrix} \\ \textsc{obj} & \begin{bmatrix} \textsc{pred} & \text{‘}\textsc{Lisa}\text{’} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(21) $$c^{2}\begin{bmatrix} \textsc{subj} & \begin{bmatrix} \textsc{pred} & \text{‘}\textsc{Homer}\text{’} \end{bmatrix} \\ \textsc{obj} & \begin{bmatrix} \textsc{pred} & \text{‘}\textsc{Bart}\text{’} \end{bmatrix} \end{bmatrix}$$

(22) is the rule responsible for gapping in Patejuk and Przepiórkowski 2017, extended here with MCs introducing existentially quantified events in gapped clauses:[1]

(22) $$\begin{array}{lllll} \text{IP} \rightarrow & \text{IP1} & \text{[Comma} & \text{IP]*} & \text{Conj} & \text{IP} \\ & \uparrow=\downarrow & & \downarrow\in\uparrow & & \downarrow\in\uparrow \\ & (\downarrow \textsc{local}) \in \uparrow & & \lambda f.\, \exists e.\, f(e) : (\downarrow_v \multimap \downarrow_t) \multimap \downarrow_t & & \lambda f.\, \exists e.\, f(e) : (\downarrow_v \multimap \downarrow_t) \multimap \downarrow_t \end{array}$$

The annotation in (22) has two effects: it creates a hybrid f-structure whose set elements include the value of LOCAL of IP1 (c^{1} from (20)) and the f-structures of all gapped conjuncts (c^{2} in (21)) and it unifies ($\uparrow=\downarrow$) the f-structure corresponding to IP1 (c in (20)) with this hybrid f-structure. As a result of unification, the PRED from c is distributed over the elements of the hybrid f-structure (c^{1} and c^{2}), producing (23) with two instantiations of PRED as the f-structure corresponding to (1).

(23) $$c\begin{bmatrix} \left\{ c^{1}\begin{bmatrix} \textsc{pred} & \text{‘}\textsc{see<}\boxed{1},\boxed{2}\textsc{>}\text{’} \\ \textsc{subj} & \boxed{1}\begin{bmatrix} \textsc{pred} & \text{‘}\textsc{Marge}\text{’} \end{bmatrix} \\ \textsc{obj} & \boxed{2}\begin{bmatrix} \textsc{pred} & \text{‘}\textsc{Lisa}\text{’} \end{bmatrix} \end{bmatrix},\ c^{2}\begin{bmatrix} \textsc{pred} & \text{‘}\textsc{see<}\boxed{3},\boxed{4}\textsc{>}\text{’} \\ \textsc{subj} & \boxed{3}\begin{bmatrix} \textsc{pred} & \text{‘}\textsc{Homer}\text{’} \end{bmatrix} \\ \textsc{obj} & \boxed{4}\begin{bmatrix} \textsc{pred} & \text{‘}\textsc{Bart}\text{’} \end{bmatrix} \end{bmatrix} \right\} \\ \textsc{local} \ \ c^{1} \\ \textsc{conj} \ \ \textsc{and} \end{bmatrix}$$

We assume that proper nouns introduce the usual MCs, e.g., $m : \uparrow_e$ for *Marge*. Thematic roles are introduced constructionally; for example, in a rule assigning the structure of a dependent to the SUBJ value of the verb, the dependent is also assumed to be an agent (perhaps as one of the options) and assigned the following MC:

(24) $\lambda x.\lambda V.\lambda f.\, V(\lambda e.\, agent(e,x) \wedge f(e)) : \downarrow_e \multimap ((\uparrow_v \multimap \uparrow_t) \multimap \uparrow_t) \multimap (\uparrow_v \multimap \uparrow_t) \multimap \uparrow_t$

These two constructors, $m : \uparrow_e$ and (24), when combined in the analysis of (1), result in the instantiated MC for the agent *Marge* in (25), where c^{1} refers to the relevant f-structure in (23), and analogously for the theme *Lisa* (as well as for the agent *Homer* and the theme *Bart* – in these cases $\uparrow$ instantiates to c^{2}).

(25) $\lambda V.\lambda f.\, V(\lambda e.\, agent(e,m) \wedge f(e)) : ((c^{1}_v \multimap c^{1}_t) \multimap c^{1}_t) \multimap (c^{1}_v \multimap c^{1}_t) \multimap c^{1}_t$

The constructor introduced under the last IP in (22) in this case instantiates to (26) and it combines with MCs for the agent *Homer* and the theme *Bart* (similar to that in (25), with c^{2}), resulting in the MC (27) corresponding to the gapped clause.

(26) $\lambda f.\, \exists e.\, f(e) : (c^{2}_v \multimap c^{2}_t) \multimap c^{2}_t$

(27) $\lambda f.\, \exists e.\, theme(e,b) \wedge agent(e,h) \wedge f(e) : (c^{2}_v \multimap c^{2}_t) \multimap c^{2}_t$

Lexical verbs introduce the following three MCs – the first one, in (28), corresponds to the closure in (11), while the next two, in (29)–(30), correspond to the representations of the semantics of verbs in (13)–(14):

(28) *saw* $\rightsquigarrow$ $\lambda e.\, true(e) : \uparrow_v \multimap \uparrow_t$

(29) $\lambda V.\, \lambda f.\, V(\lambda e.\, see(e) \wedge f(e)) : ((\uparrow_v \multimap \uparrow_t) \multimap \uparrow_t) \multimap (\uparrow_v \multimap \uparrow_t) \multimap \uparrow_t$

(30) $\lambda f.\, \exists e.\, f(e) : (\%\mathrm{v}_v \multimap \%\mathrm{v}_t) \multimap \%\mathrm{v}_t, \qquad \text{where} \quad \%\mathrm{v} = (\uparrow (\textsc{local}))$

Note that (30) relies on the variable $\%\mathrm{v}$ which can resolve to $\uparrow$ or ($\uparrow$ LOCAL). The latter is used in the analysis of gapping: in the running example (1) with the f-structure in (23), (30) instantiates to (31) and combines with the agent *Marge* and the theme *Lisa* in a way analogous to the gapped clause, resulting in the MC (32) corresponding to the first conjunct.

(31) $\lambda f.\, \exists e.\, f(e) : (c^{1}_v \multimap c^{1}_t) \multimap c^{1}_t$

(32) $\lambda f.\, \exists e.\, theme(e,l) \wedge agent(e,m) \wedge f(e) : (c^{1}_v \multimap c^{1}_t) \multimap c^{1}_t$

The resulting MCs (32) and (27) for the two conjuncts are arguments to the instantiation of the standard meaning of *and* given in (33); note that the arguments correspond to conjuncts c^{1} and c^{2}, and the result corresponds to the coordination c.

(33) $\lambda V_1.\lambda V_2.\lambda f.\, V_1(f) \wedge V_2(f) : ((c^{1}_v \multimap c^{1}_t) \multimap c^{1}_t) \multimap ((c^{2}_v \multimap c^{2}_t) \multimap c^{2}_t) \multimap (c_v \multimap c_t) \multimap c_t$

When (33) is applied to the MCs of conjuncts in (32) and (27), the result is (34) below (cf. (17) above).

(34) $\lambda f.\, [\exists e.\, theme(e,l) \wedge agent(e,m) \wedge f(e)] \wedge [\exists e.\, theme(e,b) \wedge agent(e,h) \wedge f(e)] : (c_v \multimap c_t) \multimap c_t$

The MC in (34) is input to (29), where $\uparrow$ is instantiated to c, resulting in (35) (cf. (18) above):

(35) $\lambda f.\, [\exists e.\, theme(e,l) \wedge agent(e,m) \wedge see(e) \wedge f(e)] \wedge [\exists e.\, theme(e,b) \wedge agent(e,h) \wedge see(e) \wedge f(e)] : (c_v \multimap c_t) \multimap c_t$

Finally, applying (35) to the closure in (28) results in the following final representation (cf. (19) and (2) above):

(36) $[\exists e.\, theme(e,l) \wedge agent(e,m) \wedge see(e) \wedge true(e)] \wedge [\exists e.\, theme(e,b) \wedge agent(e,h) \wedge see(e) \wedge true(e)] : c_t$

Note that the proposed analysis also covers examples where some dependents of the first conjunct are shared with the gapped conjunct, as in (37) where *Marge* can be the shared subject of both clauses (or *Maggie* can be the shared object).

(37) Marge sent Maggie to Lisa and Bart to Homer.

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[1] We assume the first-order approach to Glue (Kokkonidis 2008), with the usual basic semantic types e and t, as well as v – the type of events.

Implementation The analysis presented above has been computationally verified as an XLE+Glue (Dalrymple *et al.* 2020) implementation. In the case of the running example (1), multiple proofs result in four different meaning representations, all equivalent to (2) – they only differ in the order of conjuncts corresponding to thematic roles, depending on the order in which meaning representations of dependents combine with the meaning representation (14) ($\lambda f.\, \exists e.\, f(e)$).

Alternative Solution The above solution crucially relies on Champollion's (2015) approach to event semantics, leading to reasonable semantics of the gapped clause even without the lexical verb (see (15) or (27)). This would not be possible if the meaning of the verb were the more standard $\lambda x.\lambda y.\lambda e.\, see(e) \wedge agent(e,x) \wedge theme(e,y)$ – or the event-less $\lambda x.\lambda y.\, see(x,y)$ – and if the representations of dependents were constants, without reference to events and thematic roles.

An attempt at a more general alternative solution is inspired by an idea implemented in XLE+Glue, namely, that meaning constructors are encoded in f-structures – as members of the GLUE attribute:[2]

(38) *saw* V $(\uparrow \text{PRED}) = \text{`SEE}\langle(\uparrow \text{SUBJ}), (\uparrow \text{OBJ})\rangle\text{'}$
$\text{`}\lambda x.\lambda y.\, see(x,y) : (\uparrow \text{SUBJ})_e \multimap (\uparrow \text{OBJ})_e \multimap {\uparrow_t}\text{'} \in (\uparrow \text{GLUE})$

(39) *Marge* N $(\uparrow \text{PRED}) = \text{`MARGE'}$
$\text{`}m : {\uparrow_e}\text{'} \in (\uparrow \text{GLUE})$

If GLUE behaved like PRED (including being distributive), the syntactic analysis of gapping would produce the f-structures (40)–(41), fully analogous to (20)–(21) above, and the verb's GLUE in (40) would distribute to conjuncts, as shown in (42).[3]

(40)

$$c\left[\begin{array}{ll} \text{PRED} & \text{`SEE<SUBJ, OBJ>'} \\ \text{GLUE} & \left\{\text{`}\lambda x.\lambda y.\, see(x,y) : (\text{SUBJ})_e \multimap (\text{OBJ})_e \multimap \cdot_t\text{'}\right\} \\ \text{LOCAL} & c^{1}\left[\begin{array}{ll} \text{SUBJ} & \left[\text{PRED}\ \ \text{`MARGE'}\right] \\ \text{OBJ} & \left[\text{PRED}\ \ \text{`LISA'}\right] \end{array}\right] \end{array}\right]$$

(41)

$$c^{2}\left[\begin{array}{ll} \text{SUBJ} & \left[\text{PRED}\ \ \text{`HOMER'}\right] \\ \text{OBJ} & \left[\text{PRED}\ \ \text{`BART'}\right] \end{array}\right]$$

(42)

$$c\left[\begin{array}{l} \left\{ c^{1}\left[\begin{array}{ll} \text{PRED} & \text{`SEE<}\boxed{1},\boxed{2}\text{>'} \\ \text{GLUE} & \left\{\text{`}\lambda x.\lambda y.\, see(x,y) : \boxed{1}_e \multimap \boxed{2}_e \multimap c^{1}_t\text{'}\right\} \\ \text{SUBJ} & \boxed{1}\left[\text{PRED}\ \ \text{`MARGE'}\right] \\ \text{OBJ} & \boxed{2}\left[\text{PRED}\ \ \text{`LISA'}\right] \end{array}\right],\ c^{2}\left[\begin{array}{ll} \text{PRED} & \text{`SEE<}\boxed{3},\boxed{4}\text{>'} \\ \text{GLUE} & \left\{\text{`}\lambda x.\lambda y.\, see(x,y) : \boxed{3}_e \multimap \boxed{4}_e \multimap c^{2}_t\text{'}\right\} \\ \text{SUBJ} & \boxed{3}\left[\text{PRED}\ \ \text{`HOMER'}\right] \\ \text{OBJ} & \boxed{4}\left[\text{PRED}\ \ \text{`BART'}\right] \end{array}\right] \right\} \\ \begin{array}{ll} \text{LOCAL} & c^{1} \\ \text{CONJ} & \left[\begin{array}{ll} \text{FORM} & \text{AND} \\ \text{GLUE} & \left\{\text{`}\lambda p.\lambda q.\, p \wedge q : c^{1}_t \multimap c^{2}_t \multimap c_t\text{'}\right\} \end{array}\right] \end{array} \end{array}\right]$$

This solution would lead to the correct representation of the semantics of gapping. Unfortunately, there are two problems.

The potential conceptual problem is that syntax impinges on the resource sensitivity of Glue: while the MC which is the value of the verb's GLUE attribute is introduced just once, in the lexical entry (38), it gets multiplied via the syntactic mechanism of f-structure distributivity. We believe that such behaviour is justified and desired, but it may be controversial.

The other problem is technical: in the current implementation of XLE, there does not seem to be a way of making GLUE behave like PRED, i.e., in such a way that the $\uparrow$ metavariable used in assignments of GLUE values is instantiated independently in each conjunct (as in PRED). As verified implementationally, even though GLUE can be declared as a distributive feature, $\uparrow$ used in GLUE points to the whole coordinate structure c (instead of resolving to c^{1} in the first conjunct and c^{2} in the second), while $(\uparrow \text{SUBJ})$ gets resolved to the subsumption of the SUBJ values of the two conjuncts (and similarly for $(\uparrow \text{OBJ})$).

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[2] Due to space constraints, we gloss over the specific encoding of XLE+Glue meaning constructors here; see Dalrymple *et al.* 2020.

[3] Since GLUE is distributive, this analysis uses a slightly modified representation of conjunctions (see (42)). For space reasons, GLUE values within SUBJ and OBJ are not represented in (40)–(42).