Direct and Underspecified Interpretations of LFG f-structures

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Abstract

We describe an approach to interpreting LFG f-structures (Kaplan & Bresnan, 1982) truth-conditionally as underspecified quasi-logical forms. F-structures are either interpreted *indirectly* in terms of a homomorphic embedding into Quasi Logical Form (QLF) (Alshawi, 1992; Alshawi & Crouch, 1992; Cooper et al., 1994a) representations or *directly* in terms of adapting QLF interpretation clauses to f-structure representations. We provide a reverse mapping from QLFs to f-structures and establish isomorphic subsets of the QLF and LFG formalism. A simple mapping which switches off QLF contextual resolution can be shown to be truth preserving with respect to an independently given semantics (Dalrymple et al., 1995). We compare our proposal with approaches discussed in the literature.

1 Introduction

Different languages express grammatical functions (such as *subject* or *object*) in a variety of ways, e.g. by position or by inflection. Functional-structures (f-structures) (Kaplan & Bresnan, 1982) are attribute-value matrices that provide a *syntactic* level of representation that is intended to abstract away from such surface variations while capturing what are considered underlying generalisations. Quasi-Logical Forms (QLFs) (Alshawi & Crouch, 1992; Cooper et al., 1994a) provide the *semantic* level of representation employed in the Core Language Engine (CLE) (Alshawi, 1992). The two main characteristics of the formalism are underspecification and monotonic contextual resolution. QLFs give (partial) descriptions of intended semantic compositions. Contextual resolution monotonically adds to this description, e.g. by placing further constraints on the meanings of certain expressions like pronouns, or quantifier scope. QLFs at all stages of resolution are interpreted by a truth-conditional semantics via a supervaluation construction over the compositions meeting the description. F-structures are a mixture of mostly syntactic information (grammatical functions) with some semantic, predicate-argument information encoded via the values of PRED features:

$$\begin{bmatrix} \text{SUBJ} & \begin{bmatrix} \text{PRED} & \text{`REPRESENTATIVE'} \\ \text{NUM} & \text{SG} \\ \text{SPEC} & \text{EVERY} \end{bmatrix} \\ \text{PRED} & \text{`support } \langle \uparrow \text{SUBJ}, \uparrow \text{OBJ} \rangle\text{'} \\ \text{OBJ} & \begin{bmatrix} \text{PRED} & \text{`CANDIDATE'} \\ \text{NUM} & \text{SG} \\ \text{SPEC} & \text{A} \end{bmatrix} \end{bmatrix}$$

Unresolved QLF gives the basic predicate-argument structure of a sentence, mixed with some syntactic information encoded in the categories of QLF `terms` and `forms`:[1]

```
?Scope:support(term(+r,<num=sg,spec=every>,
                    representative,?Q,?X),
               term(+g,<num=sg,spec=a>,
                    candidate,?P,?R))
```

While there is difference in approach and emphasis unresolved QLFs and f-structures bear a striking similarity and it is easy to see how to get from one to the other:

$$\begin{bmatrix} \Gamma_1 & \gamma_1 \\ \ldots & \\ \text{PRED} & \Pi\langle \uparrow \Gamma_1, ., \uparrow \Gamma_n \rangle \\ \ldots & \\ \Gamma_n & \gamma_n \end{bmatrix}^{\circ} \rightsquigarrow \texttt{?Scope} : \Pi(\gamma_1^{\circ}, ., \gamma_n^{\circ})$$

The core of a mapping taking us from f-structures to QLFs places the values of subcategorizable grammmatical functions into their argument positions in the governing semantic form and recurses on those arguments. From this rather general perspective the difference between f-structures and

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[1] The motivation for including this syntactic information in QLFs is that resolution of such things as anaphora, ellipsis or quantifier scope may be constrained by syntactic factors (Alshawi, 1990).

QLF is one of information packaging rather than anything else. We formalise this intuition in terms of translation functions τ. The precise form of these mappings depends on whether the QLFs and f-structures to be mapped contain comparable levels of syntactic information, and in the case of QLF how this information is distributed between `term` and `form` categories and the recursive structure of the QLF. The QLF formalism deliberately leaves entirely open the amount of syntactic information that should be encoded within a QLF — the decision rests on how much syntactic information is required for successful contextual resolution. The architecture of the LFG and QLF formalism are described at length elsewhere (Kaplan & Bresnan, 1982; Alshawi & Crouch, 1992; Cooper et al., 1994a). Below we define a language of *wff-s* (*well-formed f-structures*), a (family of) translation function(s) τ from f-structures to (unresolved) QLFs and an inverse function τ^{-1} from unresolved QLFs back to f-structures. τ and τ^{-1} determine isomorphic subsets of the QLF and LFG formalism. We eliminate τ and give a direct and underspecified interpretation in terms of adapting QLF interpretation rules to f-structure representations. While the initial definition of τ is designed to maximally exploit the contextual resolution of QLF, later versions minimise resolution effects. A simple version of τ where the QLF contextual resolution component is "switched off" is truth preserving with respect to an independently given semantics (Dalrymple et al., 1995).

2 Well-formed f-structures

We define a language of *wff-s* (well-formed f-structures). The basic vocabulary consists of five disjoint sets: $GF_s = \{\text{SUBJ}, \text{OBJ}, \text{OBJ2}, \text{OBL}_\theta, \ldots\}$ (subcategorizable grammatical functions), $GF_n = \{\text{ADJS}, \text{RMODS}, \text{AMODS}, \ldots\}$ (non-subcategorizable grammatical functions), $SF = \{\text{candidate}\langle\rangle, \text{mary}\langle\rangle, \text{support}\langle\uparrow \text{SUBJ}, \uparrow \text{OBJ}\rangle, \ldots\}$ (semantic forms), $AT = \{\text{SPEC}, \text{NUM}, \text{PER}, \ldots\}$ (attributes) and $AV = \{\text{EVERY}, \text{MOST}, \text{PL}, \text{FEM}, \ldots\}$ (atomic values). The first two formation clauses pivot on the semantic form PRED values. The two final clauses cover non-subcategorizable grammatical functions and what we call *atomic* attribute-value pairs. Tags $\boxed{i}$ are used to represent reentrancies and often appear vacuously. The side condition in the second and third clause ensures that only identical substructures can have identical tags:

- if $\Pi\langle\rangle \in SF$ then $\begin{bmatrix}\text{PRED} & \Pi\langle\rangle\end{bmatrix}\boxed{i} \in \textit{wff-s}$
- if $\varphi_1\boxed{j}, \ldots, \varphi_n\boxed{k} \in \textit{wff-s}$ and $\Pi\langle\uparrow \Gamma_1, \ldots, \uparrow \Gamma_n\rangle \in SF$ then $\varphi\boxed{i} \in \textit{wff-s}$ where $\varphi\boxed{i} \equiv$
$$\begin{bmatrix}\Gamma_1 & \varphi_1\boxed{j} \\ \ldots & \\ \text{PRED} & \Pi\langle\uparrow \Gamma_1, \ldots, \uparrow \Gamma_n\rangle \\ \ldots & \\ \Gamma_n & \varphi_n\boxed{k}\end{bmatrix}\boxed{i}$$
and for any $\psi\boxed{l}$ and $\phi\boxed{m}$ occurring in $\varphi\boxed{i}$, $l \neq m$ except possibly where $\psi \equiv \phi$.
- if $\varphi_1\boxed{j}, \ldots, \varphi_n\boxed{k}, \psi\boxed{i} \in \textit{wff-s}$, where $\psi\boxed{i} \equiv \begin{bmatrix}\ldots & \\ \text{PRED} & \Pi\langle\ldots\rangle \\ \ldots & \end{bmatrix}\boxed{i}$, $\Gamma \in GF_n$ and $\Gamma \notin dom(\psi\boxed{i})$ then $\xi\boxed{i} \in \textit{wff-s}$ where $\xi\boxed{i} \equiv$
$$\begin{bmatrix}\Gamma & \{\varphi_1\boxed{j}, \ldots, \varphi_n\boxed{k}\} \\ \ldots & \\ \text{PRED} & \Pi\langle\ldots\rangle \\ \ldots & \end{bmatrix}\boxed{i}$$
and for any $\phi\boxed{l}$ and $\chi\boxed{m}$ occurring in $\xi\boxed{i}$, $l \neq m$ except possibly where $\phi \equiv \chi$.
- if $\alpha \in AT$, $v \in AV$, $\varphi\boxed{i} \in \textit{wff-s}$ where $\varphi\boxed{i} \equiv \begin{bmatrix}\ldots & \\ \text{PRED} & \Pi\langle\ldots\rangle \\ \ldots & \end{bmatrix}\boxed{i}$ and $\alpha \notin dom(\varphi\boxed{i})$ then
$$\begin{bmatrix}\alpha & v \\ \ldots & \\ \text{PRED} & \Pi\langle\ldots\rangle \\ \ldots & \end{bmatrix}\boxed{i} \in \textit{wff-s}$$

Proposition: the definition specifies f-structures that are complete, coherent and consistent.[2]

3 How to QLF an f-structure:

3.1 A Basic Mapping

Non-recursive f-structures are mapped to QLF `terms` and recursive f-structures to QLF `forms` by means of a two place function τ defined below:

- $\tau(\Gamma, \begin{bmatrix}\alpha_1 & v_1 \\ \ldots & \\ \text{PRED} & \Pi\langle\rangle \\ \ldots & \\ \alpha_n & v_n\end{bmatrix}\boxed{I}) :=$

  $\texttt{term(I,<gf=}\Gamma\texttt{,}\alpha_1 = v_1, \ldots, \alpha_n = v_n\texttt{>,}\Pi\texttt{,}$
  `?Q_I,?R_I)`
- $\tau(\Gamma, \begin{bmatrix}\Gamma_1 & \varphi_1\boxed{J} \\ \alpha_1 & v_1 \\ \ldots & \\ \text{PRED} & \Pi\langle\uparrow \Gamma_1, \ldots, \uparrow \Gamma_n\rangle \\ \ldots & \\ \Gamma_n & \varphi_n\boxed{K} \\ \alpha_m & v_m\end{bmatrix}\boxed{I}) :=$

  $\texttt{?Scope:form(I,<gf=}\Gamma\texttt{,pred=}\Pi(\Gamma_1, \ldots, \Gamma_n)$
  $\alpha_1{=}v_1, \ldots, \alpha_m{=}v_m\texttt{>,}$
  $P\text{\textasciicircum}P(\tau(\Gamma_1, \varphi_1\boxed{J}), \ldots, \tau(\Gamma_n, \varphi_n\boxed{K})),$
  `?F_I)`

  where `?Scope` is a new QLF meta-variable, P a new variable and $\alpha_i \in AT$

[2] Proof: induction on the formation rules for *wff-s* using the definitions of completeness, coherence and consistency (Kaplan & Bresnan, 1982). The notions of *substructure occurring in an f-structure* and *domain of an f-structure* can easily be spelled out formally. $\equiv$ is syntactic identity modulo permutation. The definition of *wff-s* uses graphical representations of f-structures. It can easily be recast in terms of hierarchical sets, finite functions, directed graphs etc.

To translate an f-structure, we call on τ with the first argument set to a dummy grammatical function, SIGMA. The reader may check that given

$$\left[\begin{array}{ll} \text{SUBJ} & \left[\begin{array}{ll}\text{PRED} & \text{`REPRESENTATIVE'}\\ \text{NUM} & \text{PL}\\ \text{SPEC} & \text{MOST}\end{array}\right]\boxed{g} \\ \text{PRED} & \text{`support}\ \langle\uparrow \text{SUBJ},\uparrow \text{OBJ}\rangle\text{'}\\ \text{TENSE} & \text{PAST}\\ \text{OBJ} & \left[\begin{array}{ll}\text{PRED} & \text{`CANDIDATE'}\\ \text{NUM} & \text{PL}\\ \text{SPEC} & \text{TWO}\end{array}\right]\boxed{h}\end{array}\right]\boxed{f}$$

we obtain the target QLF:

```
?Scope:form(+f,<gf=sigma,tense=past,
               pred=support(subj,obj)>,
          P^P(term(+g,<gf=subj,num=sg,
                       spec=most>,
                   representative,?Q_g,?R_g),
            term(+h,<gf=obj,num=sg,
                       spec=two>,
                   candidate,?Q_h,?R_h)),
          ?F_f).
```

The truth conditions of the resulting underspecified QLF formula are those defined by the QLF evaluation rules (Cooper et al., 1994a). The original f-structure and its component parts inherit the QLF semantics via τ. τ defines a simple *homomorphic* embedding of f-structures into QLFs. It comes as no surprise that we can eliminate τ and provide a direct underspecified interpretation for f-structures.

Note that τ as defined above maximises the use of the QLF contextual resolution component: quantifier meta-variables allow for resolution to logical quantifiers different from surface form (e.g. to cover generic readings of indefinites), as do predicate variables (in e.g. support verb constructions) etc. A definition of τ along these lines is useful in a reusability scenario where an existing LFG grammar is augmented with the QLF contextual resolution component. Alternative definitions of τ "resolve" to surface form, i.e. minimise QLF contextual resolution. Such definitions are useful in showing basic results such as preservation of truth. Below we outline how τ can be extended in order to capture more then just the basic LFG constructs and to allow for different styles of QLF construction.

3.2 F-structure reentrancies

τ respects f-structure reentrancies (indicated in terms of identical tag annotations $\boxed{i}$) without further stipulation. Consider e.g. the f-structure φ associated with the the control construction *Most representatives persuaded a manager to support every subsidiary*:

$$\left[\begin{array}{ll} \text{SUBJ} & \left[\begin{array}{ll}\text{PRED} & \text{`REPRESENTATIVE'}\\ \text{NUM} & \text{PL}\\ \text{PER} & 3\\ \text{SPEC} & \text{MOST}\end{array}\right]\boxed{g} \\ \text{PRED} & \text{`persuade}\ \langle\uparrow \text{SUBJ},\uparrow \text{OBJ},\uparrow \text{XCOMP}\rangle\text{'}\\ \text{OBJ} & \left[\begin{array}{ll}\text{PRED} & \text{`MANAGER'}\\ \text{NUM} & \text{SG}\\ \text{PER} & 3\\ \text{SPEC} & \text{A}\end{array}\right]\boxed{i}\\ \text{XCOMP} & \left[\begin{array}{ll} \text{SUBJ} & \left[\begin{array}{ll}\text{PRED} & \text{`MANAGER'}\\ \text{NUM} & \text{SG}\\ \text{PER} & 3\\ \text{SPEC} & \text{A}\end{array}\right]\boxed{i}\\ \text{PRED} & \text{`sell}\langle\uparrow\text{SUBJ},\uparrow \text{OBJ}\rangle\text{'}\\ \text{OBJ} & \left[\begin{array}{ll}\text{SPEC} & \text{EVERY}\\ \text{PRED} & \text{`subsidiary'}\\ \text{NUM} & \text{SG}\\ \text{PER} & 3\end{array}\right]\boxed{j}\end{array}\right]\boxed{h}\end{array}\right]\boxed{f}$$

where the object $\boxed{i}$ of the matix clause is token identical with the controlled subject $\boxed{i}$ of the embedded clause. φ translates into

```
?S1:form(+f,<gf=sigma,
       pred=persuade(subj,obj,xcomp)>,
       P^P(term(+g,<gf=subj,num=pl,
                  pers=3,spec=most>,
              representative,?Q_g,?R_g),
          term(+i,<gf=obj,num=sg,
                  pers=3,spec=a>,
              manager,?Q_i,?R_i),
          ?S2:form(+h,<gf=xcomp,
                  pred=support(subj,obj)
                Q^Q(term(+i,<gf=subj,
                        num=sg,pers=3,
                              spec=a>,
                     manager,?Q_i,?R_i),
                   term(+j,<gf=obj,num=sg,
                        pers=3,spec=every>,
                   subsidiary,?Q_j,?R_j)),
                  ?F_h)),
       ?F_f)
```

where the f-structure reentrancy surfaces in terms of identical QLF `term` indices `+i` and meta-variables `?Q_i`, `?R_i` as required.

3.3 Non-Subcategorizable Grammatical Functions

The treatment of modification in both f-structure and QLF is open to some flexibility and variation. Here we can only discuss some exemplary cases such as LFG analyses of N and NP pre- and post-modification. We assume an analysis involving the restriction operator in the LFG description language (Wedekind & Kaplan, 1993) and semantic form indexing ($\Pi\langle\ldots\rangle_{(i)}$ e.g. by string position) as introduced by (Kaplan & Bresnan, 1982). The f-structure associated with *The company which sold APCOM started a new subsidiary* is[3]

[3]Here and in the following we will sometimes omit tags in the f-structure representations.

$$\begin{bmatrix} \text{SUBJ} & \begin{bmatrix} \text{PRED} & \text{`COMPANY'}_{\langle 2\rangle} \\ \text{SPEC} & \text{THE} \\ \text{NUM} & \text{SG} \\ \text{GEND} & \text{NEUT} \\ \text{RM} & \left\{ \begin{bmatrix} \text{SUBJ} & \begin{bmatrix} \text{PRED} & \text{`COMPANY'}_{\langle 2\rangle} \\ \text{SPEC} & \text{THE} \\ \text{NUM} & \text{SG} \\ \text{GEND} & \text{NEUT} \end{bmatrix} \\ \text{PRED} & \text{`SELL}\ \langle\uparrow\text{SUBJ},\uparrow\text{OBJ}\rangle\text{'}_{\langle 4\rangle} \\ \text{TENSE} & \text{PAST} \\ \text{OBJ} & \begin{bmatrix} \text{PRED} & \text{`APCOM'}_{\langle 5\rangle} \\ \text{NUM} & \text{SG} \\ \text{GEND} & \text{NEUT} \end{bmatrix} \end{bmatrix} \right\} \end{bmatrix} \\ \text{PRED} & \text{`start}\langle\uparrow \text{SUBJ},\uparrow \text{OBJ}\rangle\text{'}_{\langle 6\rangle} \\ \text{OBJ} & \begin{bmatrix} \text{PRED} & \text{`SUBSIDIARY'}_{\langle 8\rangle} \\ \text{SPEC} & \text{A} \\ \text{NUM} & \text{SG} \\ \text{GEND} & \text{NEUT} \\ \text{AM} & \left\{ \begin{bmatrix} \text{PRED} & \text{`NEW'}_{\langle 7\rangle} \end{bmatrix} \right\} \end{bmatrix} \end{bmatrix}$$

We extend τ as follows:

- $\tau(\Gamma, \begin{bmatrix} \alpha_1 & v_1 \\ \dots & \\ \text{PRED} & \Pi\langle\rangle_{\langle \text{i}\rangle} \\ \dots & \\ \alpha_n & v_n \\ \text{RM} & \mathcal{R} \\ \text{AM} & \mathcal{A} \end{bmatrix} \boxed{\text{I}}) :=$

  $\texttt{term(I,<gf=}\Gamma,\alpha_1 = v_1, \dots, \alpha_n = v_n\texttt{ >,Restr,}$ $\texttt{?Q\_I,?R\_I)}$

  $\mathcal{R} \equiv \{\varrho_1, \dots, \varrho_m\}, \mathcal{A} \equiv \{\mu_1, \dots, \mu_o\},\ \varrho_1, \dots, \varrho_o,$ $\mu_1, \dots, \mu_n \in$ *wff-s*, $\mu_i \equiv [\text{PRED}\ \ \eta_i]$ and:

  $$\texttt{Restr} = \eta_1(\dots(\eta_o(\lambda x.\texttt{and}(\Pi(x), \tau_{\langle \text{i}\rangle,x}(\mathcal{R})))))$$

  $$\tau_{\langle \text{i}\rangle,x}(\mathcal{R}) = \bigwedge_{\varrho_j \in \mathcal{R}} \tau(\text{RM}, \varrho_j[\begin{bmatrix} \dots \\ \text{PRED}\ \Pi\langle\rangle_{\langle \text{i}\rangle} \\ \dots \end{bmatrix} \leftarrow x])$$

The f-structure associated with our example sentence translates into

```
?S0:
 form(+f,<gf=sigma,pred=start(subj,obj)>,
      P^P(term(+g,<gf=subj,num=sg,gend=neut,
                    spec=the>,
               x^and(company(x),
                     ?S1:form(+i,<gf=rm,
                       pred=sell(subj,obj)>,
                       Q^Q(x,
                           term(+k,<gf=obj,
                           num=sg,gend=neut>,
                           apcom,?Q_k,?R_k)),
                             ?F_i)),
               ?Q_g,?R_g),
          term(+h,<gf=obj,num=sg,
                    gend=neut,spec=a>,
               new(subsidiary),?Q_h,?R_h),
      ?F_f).
```

as required. Note, however, that the translation may overspecify the range. In the f-structure domain modifiers are collected in an unordered set while in the range we impose some arbitrary ordering. For intensional adjectives (compare *a former famous president* with *a famous former president*), this ordering may well be incorrect. Hence ordering information should be codable in (or recoverable from) the representations. In LFG this is available in terms of f-precedence. A more satisfactory translation into QLF complicates the treatment of (nominal) modification as abstracted QLF forms. Modifiers are represented as extra arguments in the body of the form and take the form index of the restriction as one of their arguments:[4]

```
x^?Scp:form(+r,<gf=np-restr,pred=subsidiary>,
          P^P(x,
              form(+a,<gf=am,pred=new>,
                   Q^Q(+r),?A)),?R)
```

Modifier ordering can then be transferred to resolution, or encoded in the categories of the restriction and modifiers to further constrain the order of application selected by resolution.

4 Direct interpretation

The core of the direct interpretation clauses for *wff-s* involves a simple variation of the quantifier rule and the predication rule of the QLF semantics (Cooper et al., 1994a). Consider the fragment without N and NP modification. As before, the semantics is defined in terms of a supervaluation construction on sets of disambiguated representations. Models, variable assignment functions, generalized quantifier interpretations and the QLF definitions for the connectives, abstraction and application etc. (see Appendix) carry over unchanged. The new quantification rule D14 non-deterministically retrieves non-recursive subcategorizable grammatical functions and employs the value of a SPEC feature in a generalized quantifier interpretation:

D14: if $\varphi, \psi(\boxed{\text{j}}) \in$ *wff-s*, $sub(\varphi, \psi(\boxed{\text{j}}))$

- if $\psi \equiv \begin{bmatrix} \text{SPEC} & \text{Q} \\ \dots & \\ \text{PRED} & \Pi\langle\rangle \\ \dots & \end{bmatrix}$ then $\mathcal{V}_g(\varphi, v)$ if $\mathcal{V}_g(Q(\lambda x.\Pi(x), \lambda x.\varphi[\psi(\boxed{\text{j}}) \leftarrow x]), v)$, x new
- if $\psi \equiv \begin{bmatrix} \dots & \\ \text{PRED} & \Pi\langle\rangle \\ \dots & \end{bmatrix}$ (i.e. SPEC $\notin dom(\psi)$) then $\mathcal{V}_g(\varphi, v)$ if $\mathcal{V}_g(\varphi[\psi(\boxed{\text{j}}) \leftarrow \Pi]), v)$

The new predication rule D10 is defined in terms of a notion of *nuclear scope* f-structure:[5]

[4] See (Cooper et al., 1994b) for examples of this style of treating VP modification.

[5] A *nuclear scope* f-structure $\varphi \in$ *nf-s* is is an f-structure resulting from exhaustive application of D14. It can be defined inductively as follows:

- if γ_i a variable or a constant symbol then $\begin{bmatrix} \Gamma_1 & \gamma_1 \\ \dots & \\ \text{PRED} & \Pi\langle\uparrow \Gamma_1, \dots, \uparrow \Gamma_n\rangle \\ \dots & \\ \Gamma_n & \gamma_n \end{bmatrix} \in$ *nf-s*

$$\textbf{D10: } \text{if } \varphi \equiv \begin{bmatrix} \Gamma_1 & \gamma_1 \\ \ldots & \\ \textsc{pred} & \Pi\langle\uparrow\Gamma_1,\ldots,\uparrow\Gamma_n\rangle \\ \ldots & \\ \Gamma_n & \gamma_n \end{bmatrix} \text{ and } \varphi \in \textit{nf-s}$$

then $\mathcal{V}_g(\varphi, v)$ if $\mathcal{V}_g(\Pi(\gamma_1,\ldots,\gamma_n), v)$

To give an example, under the direct interpretation the f-structure associated with *most representatives supported two candidates* is interpreted as an underspecified semantic representation in terms of the supervaluation over the two generalized quantifier representations

$$most(repr, \lambda x.two(cand, \lambda y.support(x,y)))$$

$$two(cand, \lambda y.most(repr, \lambda x.support(x,y)))$$

as required. The direct underspecified interpretation schema extends to the modification cases discussed above in the obvious fashion.

5 How to f-structure a QLF

The reverse mapping from QLFs to LFG f-structures ignores information conveyed by resolved meta-variables in QLF (e.g. quantifier scope, pronouns antecedents), just as the mapping from f-structure to QLF did not attempt to fill in values for these meta-variables. For QLF `terms` with simple restrictions (i.e. no modifiers), τ^{-1} is defined as follows:

- $\tau^{-1}(\texttt{term(I,<gf=}\Gamma\texttt{,}\alpha_1 = v_1,\ldots,\alpha_n = v_n\texttt{>,}\Pi\texttt{,\_,\_)}) :=$

$$\Gamma \begin{bmatrix} \alpha_1 & v_1 \\ \ldots & \\ \textsc{pred} & \Pi \\ \ldots & \\ \alpha_n & v_n \end{bmatrix} \boxed{\text{I}}$$

- $\tau^{-1}(\texttt{\_:form(I,<gf=}\Gamma\texttt{,pred=}\Pi(\Gamma_1,\ldots,\Gamma_m)\texttt{,}\alpha_1 = v_1,\ldots,\alpha_j = v_j\texttt{>,P\^{}P(}\varrho_1,\ldots,\varrho_m\texttt{),\_)}) :=$

$$\Gamma \begin{bmatrix} \alpha_1 & v_1 \\ \ldots & \\ \alpha_j & v_j \\ \textsc{pred} & \Pi\langle\uparrow\Gamma_1,\ldots,\uparrow\Gamma_M\rangle \\ \tau^{-1}(\varrho_1) & \\ \ldots & \\ \tau^{-1}(\varrho_m) & \end{bmatrix} \boxed{\text{I}}$$

As an example the reader may verify that τ^{-1} retranslates the QLF associated with *Most representatives persuaded a candidate to support every subsidiary* back into the f-structure associated with the sentence as required. Again, τ^{-1} can be extended to the non-subcategorizable grammatical functions discussed above. The extension is straightforward but messy to state in full generality and for reasons of space not given here.

- if $\gamma_i \in \textit{nf-s}$, a variable or a constant symbol then

$$\begin{bmatrix} \Gamma_1 & \gamma_1 \\ \ldots & \\ \textsc{pred} & \Pi\langle\uparrow\Gamma_1,\ldots,\uparrow\Gamma_n\rangle \\ \ldots & \\ \Gamma_n & \gamma_n \end{bmatrix} \in \textit{nf-s}$$

6 Going back and forth

Proposition: for an f-structure $\varphi \in \textit{wff-s}$[6]

$$\tau^{-1}(\tau(\varphi)) = \varphi$$

The result establishes *isomorphic* subsets of the QLF and LFG formalisms. For an arbitrary QLF ψ, however, the reverse does not hold

$$\tau(\tau^{-1}(\psi)) \neq \psi$$

F-structures do not express scope constraints etc.

7 Preservation of truth

τ assigns a meaning to an f-structure that depends on the f-structure and QLF contextual resolution. We define a restricted version τ' of τ which "switches off" the QLF contextual resolution component. τ' maps logical quantifiers to their surface form and semantic forms to QLF formulas (or resolved QLF forms):

- $$\tau'(\Gamma, \begin{bmatrix} \alpha_1 & v_1 \\ \textsc{spec} & Q \\ \ldots & \\ \textsc{pred} & \Pi\langle\rangle \\ \ldots & \\ \alpha_n & v_n \end{bmatrix} \boxed{\text{I}}) :=$$

$$\texttt{term(I,<gf=}\Gamma\texttt{,}\alpha_1 = v_1,\ldots,\alpha_n = v_n\texttt{>,}\Pi\texttt{,}Q\texttt{,I)}$$

- $$\tau'(\Gamma, \begin{bmatrix} \Gamma_1 & \varphi_1\boxed{\text{J}} \\ \alpha_1 & v_1 \\ \ldots & \\ \textsc{pred} & \Pi\langle\uparrow\Gamma_1,\ldots,\uparrow\Gamma_n\rangle \\ \ldots & \\ \Gamma_n & \varphi_n\boxed{\text{K}} \\ \alpha_m & v_m \end{bmatrix} \boxed{\text{I}}) :=$$

$$\texttt{?Scope:form(I,<gf=}\Gamma\texttt{,pred=}\Pi(\Gamma_1,\ldots,\Gamma_n)\texttt{,}$$
$$\alpha_1{=}v_1,\ldots,\alpha_m{=}v_m\texttt{>,}$$
$$\Pi(\tau(\Gamma_1,\varphi_1\boxed{\text{J}}),\ldots,\tau(\Gamma_n,\varphi_n\boxed{\text{K}}))\texttt{,}\Pi\texttt{)}$$

Proposition: τ' is truth preserving with respect to an independent semantics, e.g. the glue language semantics of (Dalrymple et al., 1995). Preservation of truth, hence correctness of the translation, is with respect to sets of disambiguations. The proof is by induction on the complexity of φ.[7] The correctness result carries over to the direct interpretation since what is eliminated is τ'.[8]

[6]Proof: induction on the complexity of φ.

[7]Proof sketch: refer to the set of disambiguated QLFs resulting from $\tau'(\varphi)$ through application of the QLF interpretation clauses as $\mathcal{V}(\tau'(\varphi))$ and to the set of conclusions obtained trough linear logic deduction from the premisses of the σ projections of φ as $(\sigma(\varphi))_{\vdash}$. Consider the fragment without modification. Base case: for φ with nonrecursive values of grammatical functions show $\mathcal{V}(\tau'(\varphi)) = (\sigma(\varphi))_{\vdash}$. Induction: for φ with possibly recursive values φ_i of grammatical functions on the assumption that for each i: $\mathcal{V}(\tau'(\varphi_i)) = (\sigma(\varphi_i))_{\vdash}$ (IH) show $\mathcal{V}(\tau'(\varphi)) = (\sigma(\varphi))_{\vdash}$.

[8]If the results of linear logic deductions are interpreted in terms of the supervaluation construction we have preservation of truth directly with respect to underspecified representations, QLFs and sets of linear logic premisses.

8 Conclusion and Comparison

We have provided direct and indirect underspecified model theoretic interpretations for LFG f-structures. The interpretations are truth preserving, hence correct, with respect to an independent semantics. We have established isomorphic subsets of the QLF and LFG formalism. Our approach is in the spirit of but contrasts with approaches by (Halvorsen, 1983; Halvorsen & Kaplan, 1988; Fenstad et al., 1987; Wedekind & Kaplan, 1993; Dalrymple et al., 1995) which are neither underspecified nor direct. Like (Halvorsen, 1983; Wedekind & Kaplan, 1993) our approach falls into the *description by analysis* paradigm. Its limits are determined by what is analysed: f-structures. Work is under way to interpret f-structures as UDRSs in order to exploit the UDRS inference component (Reyle, 1993). Further work reconstructs QLF interpretation in terms of linear logic deductions (Dalrymple et al., 1995) and provides a scope constraint mechanism for such deductions.

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Appendix: Quasi Logical Forms

Here we can only outline the parts of the syntax and semantics of QLF (for a full account see (Alshawi & Crouch, 1992; Cooper et al., 1994a)) most relevant for our present purposes. A QLF `term` must be an individual variable, an individual constant or a complex term expression. A QLF `formula` must be an application of a predicate to arguments possibly with scoping constraints or a `form` expression:

```
term ::= x | c | term(Id,Cat,Restr,Qnt,Ref)
formula ::= Scope:Pred(Arg_1,...,Arg_n)
          | Scope:form(Id,Cat,Restr,Res)
```

The QLF semantics is defined in terms of a supervaluation construction with standard higher order models in terms of a valuation relation $\mathcal{V}(\phi, v)$ which disambiguates a QLF ϕ with respect to a context in terms of a salience relation $\mathcal{S}$(C,P) between syntactic category descriptions C and QLF context representations P:

- $[\![\phi]\!]^{M,g} = 1$ iff $\mathcal{V}(\phi, 1)$ but not $\mathcal{V}(\phi, 0)$
- $[\![\phi]\!]^{M,g} = 0$ iff $\mathcal{V}(\phi, 0)$ but not $\mathcal{V}(\phi, 1)$
- $[\![\phi]\!]^{M,g}$ *undefined* iff $\mathcal{V}(\phi, 1)$ and $\mathcal{V}(\phi, 0)$

Q1: $\mathcal{V}_g(\texttt{and}(\phi, \psi), 1)$ if $\mathcal{V}_g(\phi, 1)$ and $\mathcal{V}_g(\psi, 1)$

Q2: $\mathcal{V}_g(\texttt{and}(\phi, \psi), 0)$ if $\mathcal{V}_g(\phi, 0)$ or $\mathcal{V}_g(\psi, 0)$

...

Q10: $\mathcal{V}_g(p(arg_1, \ldots, arg_n), P(Arg_1, \ldots, Arg_n))$ if $\mathcal{V}_g(p, P)$ and $\mathcal{V}_g(arg_1, Arg_1)$ and ...and $\mathcal{V}_g(arg_n, Arg_n)$

...

Q12: if ϕ is a formula containing a term `term(I,C,R,?Q,?R)` and Q is a quantifier such that $\mathcal{S}(C, Q)$ then $\mathcal{V}_g(\phi, v)$ if $\mathcal{V}_g(\phi[Q/\texttt{?Q}, I/\texttt{?R}], v)$

...

Q14: if ϕ is a formula containing a term `T = term(I,C,R,Q,A)` then $\mathcal{V}_g(\phi, v)$ if $\mathcal{V}_g(\texttt{Q(R',F')}, v)$ where
`R'` is `X^(and(R(X),X=A))[X/I]`, and
`F'` is `X^(and(`ϕ`,X=A))[X/T,X/I]`

Q15: if `[I,J,...]:`ϕ is a formula containing a term `T = term(I,C,R,Q,A)` then $\mathcal{V}_g(\texttt{[I,J,...]:}\phi, v)$ if $\mathcal{V}_g(\texttt{Q(R',F')}, v)$ where
`R'` is `X^(and(R(X),X=A))[X/I]`, and
`F'` is `X^([J,...]:and(`ϕ`,X=A))[X/T,X/I]`

Q16: $\mathcal{V}_g(\texttt{form(I,C,R,?R)}, v)$ if $\mathcal{V}_g(\texttt{(R(P)}, v)$ where $\mathcal{S}$(C,P)

Q17: $\mathcal{V}_g(\texttt{form(I,C,R,}\phi\texttt{)}, v)$ if $\mathcal{V}_g(\texttt{(R(}\phi\texttt{)}, v)$ where ϕ is a QLF expression but not a meta-variable