Logic to MRS Mapping: Paraphrasing for HyperProof

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Overview

- Online course on introductory logic

    Book: Barwise and Etchemendy, *Language, Proof, and Logic*

- Students are presented with an English statement

- Their task is to produce a first-order logic expression of it

- We want an engine that generates English paraphrases of an FOL

    Produce English for auto-generated course FOL to start task

    Restate student's incorrect FOL as English for instruction

Method

- Convert FOL to skeletal MRS (Python script)

- Inflate skeletal MRS to full MRS for generator using ACE 'transfer' rules

- Apply LOGON-style paraphrase rules using ACE to produce variant MRSs

- Generate from each of these paraphrase MRSs using ACE

- Select one of these outputs to present to the student

An example

```
large(a)&large(b)
```

```
[ LTOP: h1
  INDEX: e1
  RELS: < [ "name" LBL: h3 ARG0: x1 CARG: "A" ]
          [ "large" LBL: h4 ARG0: e2 ARG1: x1 ]
          [ "name" LBL: h5 ARG0: x2 CARG: "B" ]
          [ "large" LBL: h6 ARG0: e3 ARG1: x2 ]
          [ "and" LBL: h2 ARG0: e1 L-INDEX: e2 R-INDEX: e3 ] > ]
```

Inflated MRS

large(a)&large(b)

```
[ LTOP: h20
INDEX: e13 [ e SORT: collective SF: prop TENSE: pres PERF: - ]
RELS: <
 [ named_rel LBL: h5 ARG0: x10 [ x PERS: 3 NUM: sg ] CARG: "A" ]
 [ named_rel LBL: h9 ARG0: x11 [ x PERS: 3 NUM: sg ] CARG: "B" ]
 [ proper_q_rel LBL: h2 ARG0: x10 RSTR: h3 BODY: h4 ]
 [ proper_q_rel LBL: h6 ARG0: x11 RSTR: h7 BODY: h8 ]
 [ "_large_a_1_rel" LBL: h18
                       ARG0: e14 [ e SF: prop TENSE: pres PERF: - ]
                       ARG1: x10 ]
 [ "_large_a_1_rel" LBL: h19
                       ARG0: e15 [ e SF: prop TENSE: pres PERF: - ]
                       ARG1: x11 ]
 [ _and_c_rel LBL: h12 ARG0: e13 L-INDEX: e14 R-INDEX: e15
                            L-HNDL: h16 R-HNDL: h17 ] >
HCONS: < h3 qeq h5 h7 qeq h9 h16 qeq h18 h17 qeq h19 > ]
```

Generated paraphrases

$$cube(a)\&cube(b)$$

A and B are large.
A is large and B is large.
A is large, and B is large.
Both A and B are large.

Another example

```
(cube(a)&cube(b))-->leftof(a,b)
```

```
[ LTOP: h1
  INDEX: e5
  RELS: < [ "name" LBL: h4 ARG0: x1 CARG: "A" ]
          [ "cube" LBL: h5 ARG0: e3 ARG1: x1 ]
          [ "name" LBL: h6 ARG0: x2 CARG: "B" ]
          [ "cube" LBL: h7 ARG0: e4 ARG1: x2 ]
          [ "and" LBL: h3 ARG0: e2 L-INDEX: e3 R-INDEX: e4 ]
          [ "name" LBL: h8 ARG0: x3 CARG: "A" ]
          [ "name" LBL: h9 ARG0: x4 CARG: "B" ]
          [ "leftof" LBL: h10 ARG0: e5 ARG1: x3 ARG2: x4 ]
          [ "if" LBL: h2 ARG0: e1 L-INDEX: e2 R-INDEX: e5 ] > ]
```

Inflated MRS again

```
[ LTOP: h55
INDEX: e56 [ e SF: prop TENSE: pres PERF: - ]
RELS: < [ named_rel LBL: h7 ARG0: x20 [ x PERS: 3 NUM: sg ] CARG: "A" ]
  [ named_rel LBL: h11 ARG0: x21 [ x PERS: 3 NUM: sg ] CARG: "B" ]
  [ named_rel LBL: h15 ARG0: x28 [ x PERS: 3 NUM: sg ] CARG: "A" ]
  [ named_rel LBL: h19 ARG0: x24 [ x PERS: 3 NUM: sg ] CARG: "B" ]
  [ proper_q_rel LBL: h4 ARG0: x20 RSTR: h5 BODY: h6 ]
  [ proper_q_rel LBL: h8 ARG0: x21 RSTR: h9 BODY: h10 ]
  [ proper_q_rel LBL: h12 ARG0: x28 RSTR: h13 BODY: h14 ]
  [ proper_q_rel LBL: h16 ARG0: x24 RSTR: h17 BODY: h18 ]
  [ _be_v_id_rel LBL: h44 ARG0: e40 [ e SF: prop TENSE: pres PERF: - ] ARG1: x20 ARG2: x30 ]
  [ "_cube_n_1_rel" LBL: h33 ARG0: x30 ]
  [ _be_v_id_rel LBL: h45 ARG0: e41 [ e SF: prop TENSE: pres PERF: - ] ARG1: x21 ARG2: x35 ]
  [ "_cube_n_1_rel" LBL: h38 ARG0: x35 ]
  [ "_left_n_of_rel" LBL: h22 ARG0: x23 [ x PERS: 3 NUM: sg ] ARG1: x24 ]
  [ _the_q_rel LBL: h25 ARG0: x23 RSTR: h26 BODY: h27 ]
  [ _to_p_rel LBL: h53 ARG0: e56 ARG1: x28 ARG2: x23 ]
  [ udef_a_q_rel LBL: h29 ARG0: x30 RSTR: h31 BODY: h32 ]
  [ udef_a_q_rel LBL: h34 ARG0: x35 RSTR: h36 BODY: h37 ]
  [ _and_c_rel LBL: h54 ARG0: e39 [ e SORT: collective SF: prop TENSE: pres PERF: - ] L-INDEX: e40 R-INDEX: e41 L-HNDL: h42 R-HNDL:
  [ "_if_x_then_rel" LBL: h46 ARG0: e47 [ e SF: prop TENSE: untensed ] ARG1: h48 ARG2: h49 ]
  [ "_then_a_1_rel" LBL: h50 ARG0: e51 [ e SF: prop TENSE: untensed ] ARG1: h52 ] >
HCONS: < h5 qeq h7 h9 qeq h11 h13 qeq h15 h17 qeq h19 h26 qeq h22 h31 qeq h33 h36 qeq h38 h42 qeq h44 h43 qeq h45 h48 qeq h50 h52 q
```

Generated paraphrases

```
(cube(a)&cube(b))-->leftof(a,b)
```

If A and B are cubes then A is to the left of B.
If A and B are cubes, then A is to the left of B.
If A is a cube and B is a cube then A is to the left of B.
If A is a cube and B is a cube, then A is to the left of B.
If A is a cube, and B is a cube then A is to the left of B.
If A is a cube, and B is a cube, then A is to the left of B.
If both A and B are cubes then A is to the left of B.
If both A and B are cubes, then A is to the left of B.

A paraphrase rule

```
basic_vp_ellipsis_gpr := monotonic_mtr &
[ CONTEXT.RELS.LIST < [ PRED #pred, ARG0 event ], ...>,
  FILTER.RELS <! [ PRED comp_rel ] !>,
  INPUT [ HOOK.INDEX #index,
  RELS.LIST < [ PRED #pred, LBL #h1 & handle,
                           ARG0 #e2 & event,
ARG1 #x3 & ref-ind ], ... > ],
  OUTPUT [ HOOK.INDEX #index,
   RELS <! [ PRED ellipsis_ref_rel, LBL #h1,
           ARG0 #e2 & [ E.TENSE present ],
              ARG1 #x3 ] !> ] ].
```

Development examples

```
tet(a)-->frontof(a,d)
(leftof(a,d)|rightof(a,d))-->cube(a)
between(c,a,e)|between(c,a,d)
small(c)-->rightof(c,a)
rightof(c,d)-->(rightof(b,c)&leftof(b,e))
tet(e)-->(rightof(e,b)<->frontof(e,b))
dodec(b)-->(-frontof(b,d)-->-backof(b,d))
backof(c,a)&frontof(c,e)
-(large(e)&tet(e))-->frontof(e,d)
cube(a)|cube(c)|cube(e)
tet(a)-->frontof(a,b)
larger(b,a)&larger(b,e)
(larger(a,c)&larger(e,c))&-(large(a)|large(e))
sameshape(d,b)-->samesize(d,b)
large(a)<->cube(a)
-tet(c)-->cube(b)
-(cube(e))-->(large(b)|large(d))
(tet(a)|tet(c))-->(cube(b)|cube(d))
large(a)<->small(d)
```

A more interesting example

(larger(a,c)&larger(e,c))&-(large(a)ORlarge(e))

A and E are both larger than C but neither of them is large.

A more interesting example

A and E are both larger than C and it is not the case either that A is large or that E is large.
A and E are both larger than C and it is not the case either that A is large, or that E is large.
A and E are both larger than C, and it is not the case either that A is large or that E is large.
A and E are both larger than C, and it is not the case either that A is large, or that E is large.
A and E are both larger than C and it is not the case that A is large or E is large.
A and E are both larger than C and it is not the case that A is large, or E is large.
A and E are both larger than C, and it is not the case that A is large or E is large.
A and E are both larger than C, and it is not the case that A is large, or E is large.
A and E are both larger than C and it is not the case that A is large or that E is large.
A and E are both larger than C and it is not the case that A is large, or that E is large.
A and E are both larger than C, and it is not the case that A is large or that E is large.
A and E are both larger than C, and it is not the case that A is large, or that E is large.
A and E are both larger than C and it is not the case that A or E is large.
A and E are both larger than C, and it is not the case that A or E is large.
A and E are both larger than C and it is not the case that either A is large or E is large.
A and E are both larger than C and it is not the case that either A is large, or E is large.
A and E are both larger than C, and it is not the case that either A is large or E is large.
A and E are both larger than C, and it is not the case that either A is large, or E is large.
A and E are both larger than C and it is not the case that either A or E is large.
A and E are both larger than C, and it is not the case that either A or E is large.
A and E are both larger than C and it isn't the case either that A is large or that E is large.
A and E are both larger than C and it isn't the case either that A is large, or that E is large.
A and E are both larger than C, and it isn't the case either that A is large or that E is large.
A and E are both larger than C, and it isn't the case either that A is large, or that E is large.
A and E are both larger than C and it isn't the case that A is large or E is large.
A and E are both larger than C and it isn't the case that A is large, or E is large.
A and E are both larger than C, and it isn't the case that A is large or E is large.
A and E are both larger than C, and it isn't the case that A is large, or E is large.
A and E are both larger than C and it isn't the case that A is large or that E is large.
A and E are both larger than C and it isn't the case that A is large, or that E is large.
A and E are both larger than C, and it isn't the case that A is large or that E is large.
A and E are both larger than C, and it isn't the case that A is large, or that E is large.
A and E are both larger than C and it isn't the case that A or E is large.

A more interesting example

A and E are both larger than C, and it isn't the case that A or E is large.
A and E are both larger than C and it isn't the case that either A is large or E is large.
A and E are both larger than C and it isn't the case that either A is large, or E is large.
A and E are both larger than C, and it isn't the case that either A is large or E is large.
A and E are both larger than C, and it isn't the case that either A is large, or E is large.
A and E are both larger than C and it isn't the case that either A or E is large.
A and E are both larger than C, and it isn't the case that either A or E is large.
A and E are both larger than C and it's not the case either that A is large or that E is large.
A and E are both larger than C and it's not the case either that A is large, or that E is large.
A and E are both larger than C, and it's not the case either that A is large or that E is large.
A and E are both larger than C, and it's not the case either that A is large, or that E is large.
A and E are both larger than C and it's not the case that A is large or E is large.
A and E are both larger than C and it's not the case that A is large, or E is large.
A and E are both larger than C, and it's not the case that A is large or E is large.
A and E are both larger than C, and it's not the case that A is large, or E is large.
A and E are both larger than C and it's not the case that A is large or that E is large.
A and E are both larger than C and it's not the case that A is large, or that E is large.
A and E are both larger than C, and it's not the case that A is large or that E is large.
A and E are both larger than C, and it's not the case that A is large, or that E is large.
A and E are both larger than C and it's not the case that A or E is large.
A and E are both larger than C, and it's not the case that A or E is large.
A and E are both larger than C and it's not the case that either A is large or E is large.
A and E are both larger than C and it's not the case that either A is large, or E is large.
A and E are both larger than C, and it's not the case that either A is large or E is large.
A and E are both larger than C, and it's not the case that either A is large, or E is large.
A and E are both larger than C and it's not the case that either A or E is large.
A and E are both larger than C, and it's not the case that either A or E is large.
A and E are both larger than C and neither A nor E is large.
A and E are both larger than C, and neither A nor E is large.
A and E are both larger than C and neither is large.
A and E are both larger than C, and neither is large.
A and E are both larger than C and neither of them is large.
A and E are both larger than C, and neither of them is large.
A and E are both larger than C but it is not the case either that A is large or that E is large.

A and E are both larger than C but it is not the case either that A is large, or that E is large.

A more interesting example

A and E are both larger than C, but it is not the case either that A is large or that E is large.
A and E are both larger than C, but it is not the case either that A is large, or that E is large.
A and E are both larger than C but it is not the case that A is large or E is large.
A and E are both larger than C but it is not the case that A is large, or E is large.
A and E are both larger than C, but it is not the case that A is large or E is large.
A and E are both larger than C, but it is not the case that A is large, or E is large.
A and E are both larger than C but it is not the case that A is large or that E is large.
A and E are both larger than C but it is not the case that A is large, or that E is large.
A and E are both larger than C, but it is not the case that A is large or that E is large.
A and E are both larger than C, but it is not the case that A is large, or that E is large.
A and E are both larger than C but it is not the case that A or E is large.
A and E are both larger than C, but it is not the case that A or E is large.
A and E are both larger than C but it is not the case that either A is large or E is large.
A and E are both larger than C but it is not the case that either A is large, or E is large.
A and E are both larger than C, but it is not the case that either A is large or E is large.
A and E are both larger than C, but it is not the case that either A is large, or E is large.
A and E are both larger than C but it is not the case that either A or E is large.
A and E are both larger than C, but it is not the case that either A or E is large.
A and E are both larger than C but it isn't the case either that A is large or that E is large.
A and E are both larger than C but it isn't the case either that A is large, or that E is large.
A and E are both larger than C, but it isn't the case either that A is large or that E is large.
A and E are both larger than C, but it isn't the case either that A is large, or that E is large.
A and E are both larger than C but it isn't the case that A is large or E is large.
A and E are both larger than C but it isn't the case that A is large, or E is large.
A and E are both larger than C, but it isn't the case that A is large or E is large.
A and E are both larger than C, but it isn't the case that A is large, or E is large.
A and E are both larger than C but it isn't the case that A is large or that E is large.
A and E are both larger than C but it isn't the case that A is large, or that E is large.
A and E are both larger than C, but it isn't the case that A is large or that E is large.
A and E are both larger than C, but it isn't the case that A is large, or that E is large.
A and E are both larger than C but it isn't the case that A or E is large.
A and E are both larger than C, but it isn't the case that A or E is large.
A and E are both larger than C but it isn't the case that either A is large or E is large.
A and E are both larger than C but it isn't the case that either A is large, or E is large.

A and E are both larger than C, but it isn't the case that either A is large or E is large.

A more interesting example

A and E are both larger than C but neither A nor E is large.
A and E are both larger than C, but neither A nor E is large.
A and E are both larger than C but neither is large.
A and E are both larger than C, but neither is large.
A and E are both larger than C but neither of them is large.
A and E are both larger than C, but neither of them is large.
A and E are both larger than C; however it is not the case either that A is large or that E is large.
A and E are both larger than C; however it is not the case either that A is large, or that E is large.
A and E are both larger than C; however, it is not the case either that A is large or that E is large.
A and E are both larger than C; however, it is not the case either that A is large, or that E is large.
A and E are both larger than C; however it is not the case that A is large or E is large.
A and E are both larger than C; however it is not the case that A is large, or E is large.
A and E are both larger than C; however, it is not the case that A is large or E is large.
A and E are both larger than C; however, it is not the case that A is large, or E is large.
A and E are both larger than C; however it is not the case that A is large or that E is large.
A and E are both larger than C; however it is not the case that A is large, or that E is large.
A and E are both larger than C; however, it is not the case that A is large or that E is large.
A and E are both larger than C; however, it is not the case that A is large, or that E is large.
A and E are both larger than C; however it is not the case that A or E is large.
A and E are both larger than C; however, it is not the case that A or E is large.
A and E are both larger than C; however it is not the case that either A is large or E is large.
A and E are both larger than C; however it is not the case that either A is large, or E is large.
A and E are both larger than C; however, it is not the case that either A is large or E is large.
A and E are both larger than C; however, it is not the case that either A is large, or E is large.
A and E are both larger than C; however it is not the case that either A or E is large.
A and E are both larger than C; however, it is not the case that either A or E is large.
A and E are both larger than C; however it isn't the case either that A is large or that E is large.
A and E are both larger than C; however it isn't the case either that A is large, or that E is large.
A and E are both larger than C; however, it isn't the case either that A is large or that E is large.
A and E are both larger than C; however, it isn't the case either that A is large, or that E is large.
A and E are both larger than C; however it isn't the case that A is large or E is large.
A and E are both larger than C; however it isn't the case that A is large, or E is large.

A and E are both larger than C; however, it isn't the case that A is large or E is large.

Paraphrase phenomena

- Coordination

    Subjects (*A and B are large*)

    Predicates (*B is a cube and is large*)

- Negation (*It is not the case that A and B are large*)

- Pronouns (*If B is a cube, it is large*)

- Partitives (*one of, both of*)

- VP ellipsis (*If B is large, then C is*)

- Sentence connectives (*if and only if, just in case, unless*)

- Adjectives (predicative or prenominal)

- Adverbs (addition or deletion) (*If A is large, B is also large*)

Next steps

- Augment output to report which rule(s) applied per sentence

- Enable control of which paraphrase rules to apply

- Test system in classroom this fall

- Expand system to include quantifiers