A Data-Driven Approach to Deep Machine Translation

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Overview

- Motivation
  - Characterisation of statistical and transfer-based MT
  - Hybrid system idea
- Automatic acquisition of transfer rules
  - Workflow
  - Example
  - Some details
- Evaluation
- Outlook

Statistical Machine Translation

- Quick to develop
  - Translation model learned from parallel corpora
  - Target language model learned from monolingual corpora

- High coverage
  - Covers all technical terms etc. if seen in training data
    - e.g. *Steueroase / paradis fiscal* → *tax haven*
  - Robust: always delivers some output

but...

Statistical Machine Translation

- Problems with syntactically or semantically more complex input (examples from Google Translate):

Der von Browne gejagte Hund bellte.
(R: The dog chased by Browne barked.)
→ *The Hunted Browne dog barked.* (March 2008)
→ *The Browne gejagte dog barked.* (May 2008)

Der von der Katze gejagte Hund bellte.
(R: The dog chased by the cat barked.)
→ *The cat Hunted by the dog barked.* (March 2008)
→ *The cat gejagte the dog barked.* (May 2008)

Statistical Machine Translation

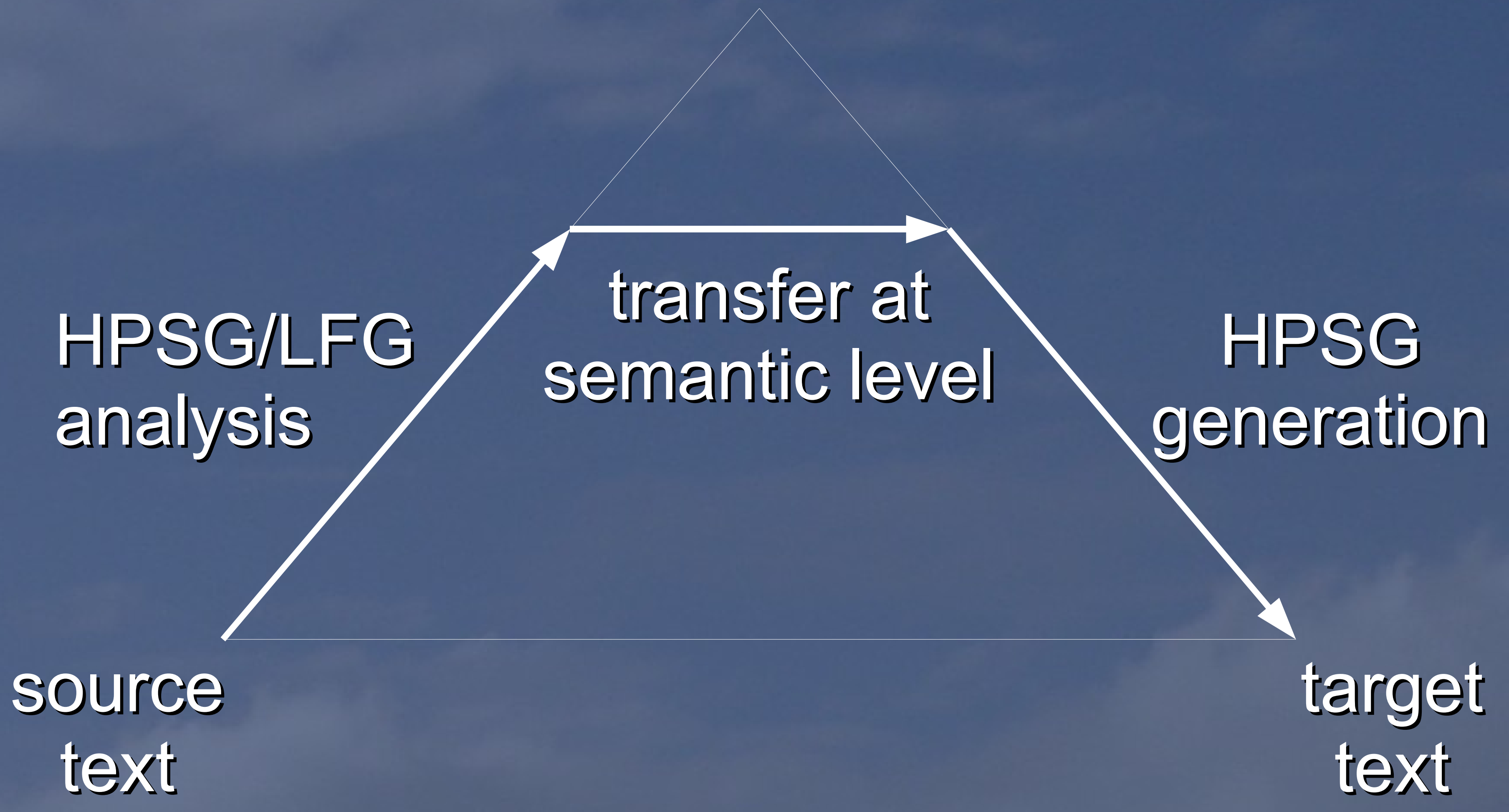
- Problems with syntactically or semantically more complex input (examples from Google Translate):

  Abrams versprach Browne zu bellen.
  (R: Abrams promised Browne to bark.)
  → *Abrams Browne promised to bark.* (March 2008)
  → *Abrams promised Browne to bark.* (May 2008)

  Michael versprach Georg zu bellen.
  (R: Michael promised Georg to bark.)
  → *George Michael promised to bark.* (May 2008)

Deep Transfer-Based Machine Translation

- LOGON project



HPSG/LFG analysis

transfer at semantic level

HPSG generation

source text

target text

Deep Transfer-Based Machine Translation

- Minimal Recursion Semantics example

  Der Hund jagt die Katze. (The dog chases the cat.)

```
[ LTOP: h1
  INDEX: e2 [ e MOOD: INDICATIVE TENSE: PRESENT ]
  RELS: <
      [ "_def_q_rel"                           [ "_def_q_rel"          [ "_jagen_v_rel"
        LBL: h3                                  LBL: h10                LBL: h8
        ARG0: x5 [ x PERS: 3 NUM: SG ]           ARG0: x9                ARG0: e2
        RSTR: h4                                 RSTR: h11               ARG1: x5
        BODY: h6 ]                               BODY: h12 ]             ARG2: x9 [ x PERS: 3 NUM: SG ] ]

      [ "_hund_n_rel"                          [ "_katze_n_rel"        [ prop-or-ques_m_rel
        LBL: h7                                  LBL: h13                LBL: h1
        ARG0: x5 ]                               ARG0: x9 ]              ARG0: e2
                                                                         MARG: h14
                                                                         TPC: x5 ] >

                                                         HCONS: < h14 qeq h8 h4 qeq h7 h11 qeq h13 > ]
```

Deep Transfer-Based Machine Translation

- Advantages
  - Preserves meaning
  - Grammatical output
- Disadvantages
  - High development cost due to manual rule production
  - Weak on idiomaticity, e.g. *paradis fiscal* → *fiscal paradise*
  - Low coverage, e.g. *Steueroase* probably not in lexicon

Complementary Approaches to MT

- Idea: Combine advantages by learning transfer rules from parallel corpora

	SMT	DTBMT	Hybrid
development speed	+	-	+
grammaticality	-	+	+
lexical semantics	+	-	+
structural semantics	-	+	+
coverage	+	-	-(?)

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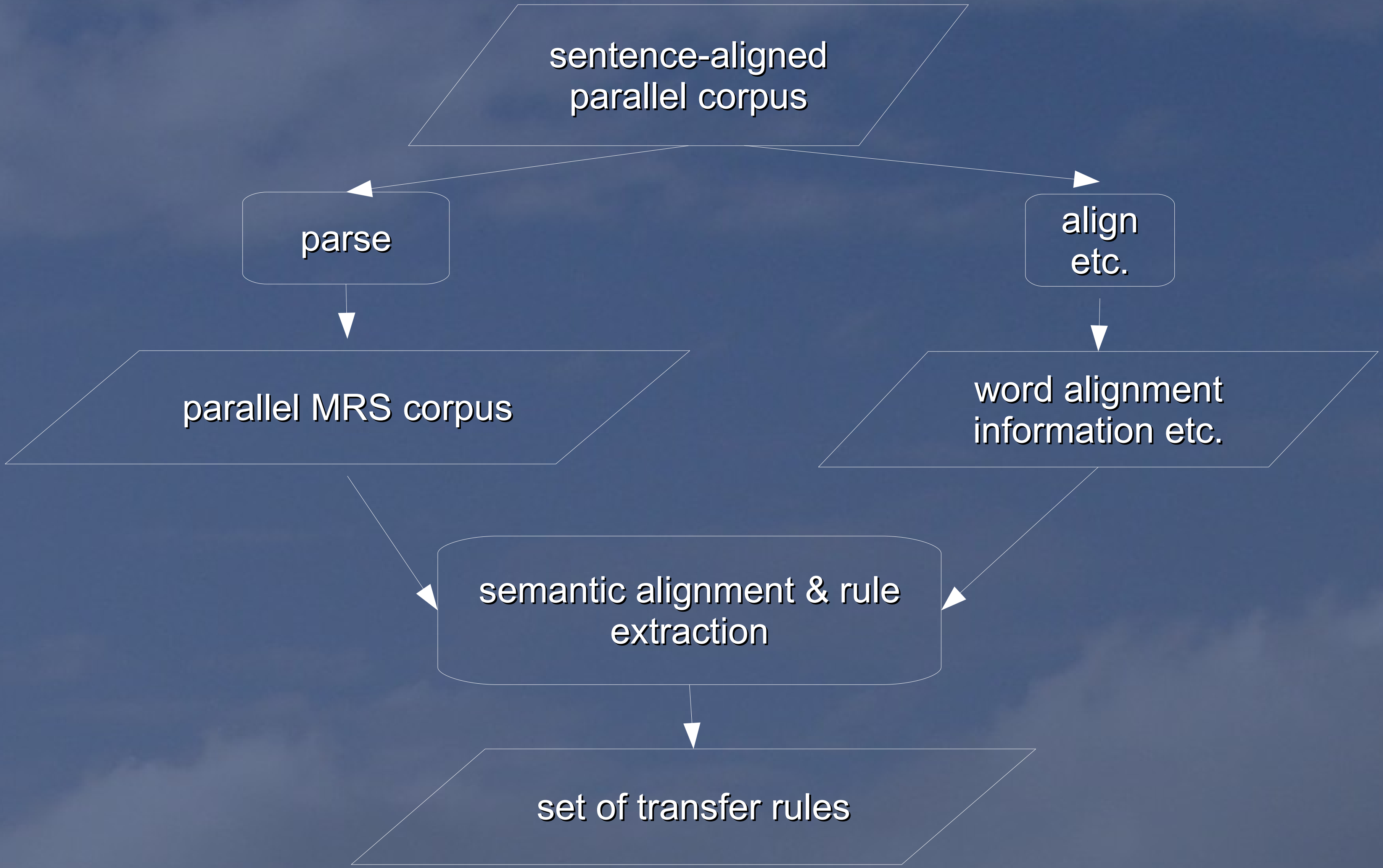
Transfer Rule Acquisition Workflow


sentence-aligned parallel corpus
parse
align etc.
parallel MRS corpus
word alignment information etc.
semantic alignment & rule extraction
set of transfer rules

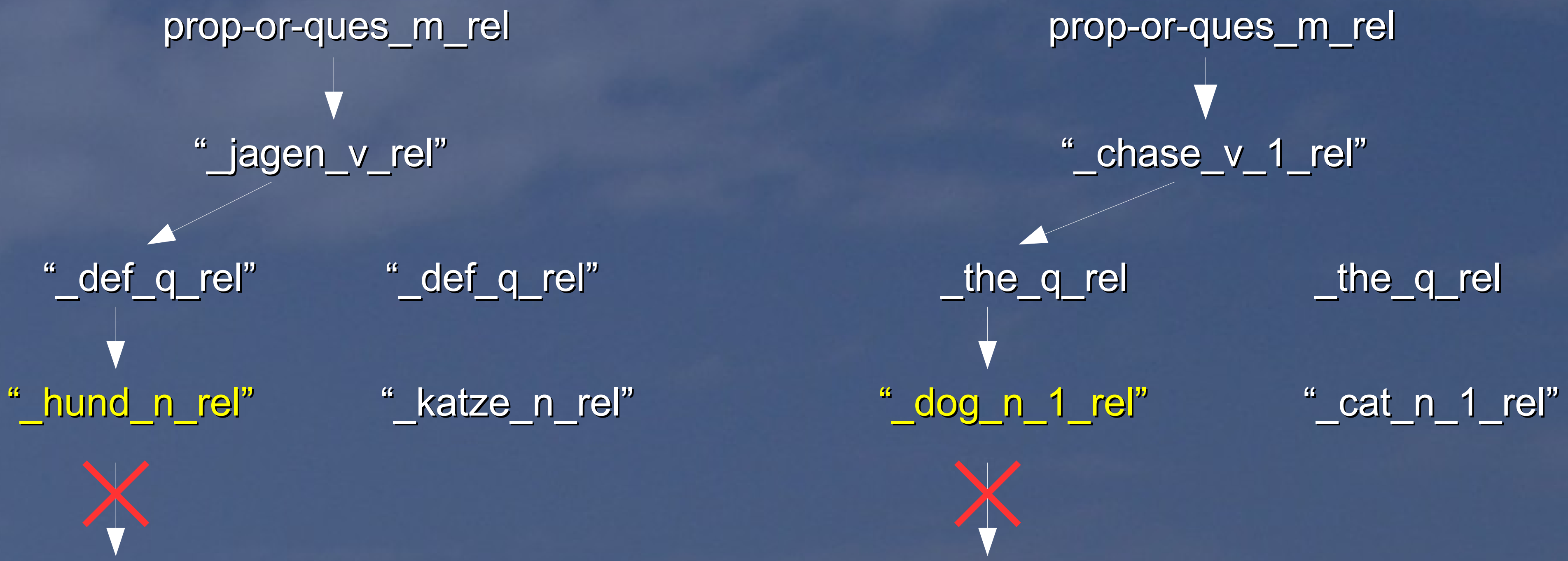
Deep Transfer-Based Machine Translation

- Minimal Recursion Semantics example

  Der Hund jagt die Katze. (The dog chases the cat.)

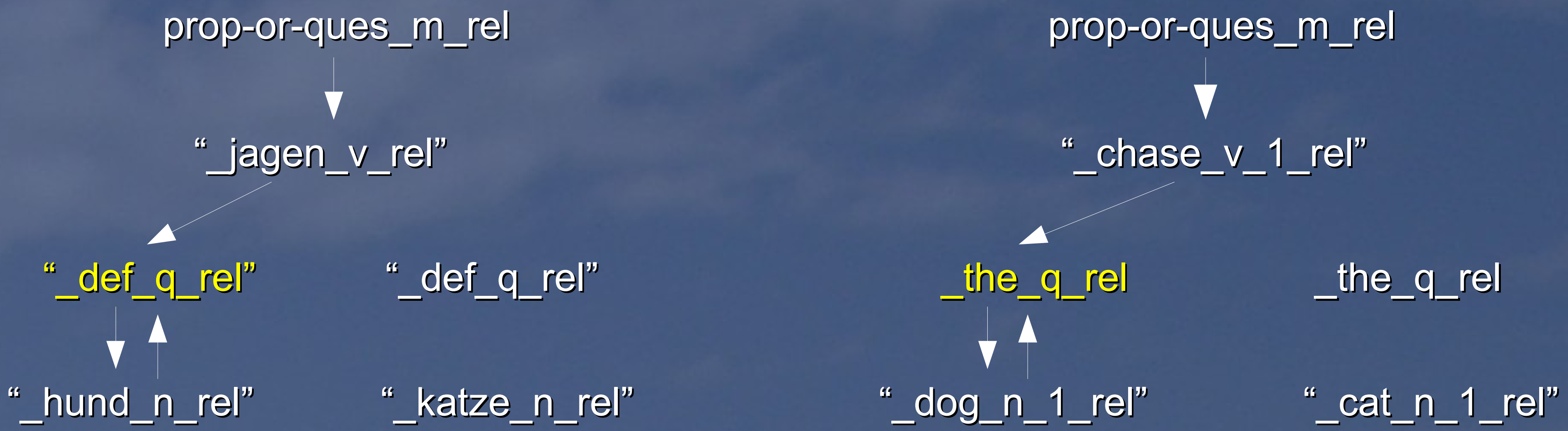
```
[ LTOP: h1
  INDEX: e2 [ e MOOD: INDICATIVE TENSE: PRESENT ]
  RELS: <
       [ "_def_q_rel"                        [ "_def_q_rel"          [ "_jagen_v_rel"
         LBL: h3                               LBL: h10                LBL: h8
         ARG0: x5 [ x PERS: 3 NUM: SG ]        ARG0: x9                ARG0: e2
         RSTR: h4                              RSTR: h11               ARG1: x5
         BODY: h6 ]                            BODY: h12 ]             ARG2: x9 [ x PERS: 3 NUM: SG ] ]

       [ "_hund_n_rel"                       [ "_katze_n_rel"        [ prop-or-ques_m_rel
         LBL: h7                               LBL: h13                LBL: h1
         ARG0: x5 ]                            ARG0: x9 ]              ARG0: e2
                                                                       MARG: h14
                                                                       TPC: x5 ] >

                                                                HCONS: < h14 qeq h8 h4 qeq h7 h11 qeq h13 > ]
```

Transfer Rule Acquisition Example



```
dog_rule_0 := monotonic_omtr &
 [ INPUT [ RELS < [ PRED "_dog_n_1_rel", LBL #1, ARG0 #2 & [PERS #3, NUM #4] ] > ],
 OUTPUT [ RELS < [ PRED "_hund_n_rel", LBL #1, ARG0 #2 & [PERS #3, NUM #4] ] > ] ].
```

Transfer Rule Acquisition Example



prop-or-ques_m_rel

“_jagen_v_rel”

“_def_q_rel”

“_def_q_rel”

“_hund_n_rel”

“_katze_n_rel”

prop-or-ques_m_rel

“_chase_v_1_rel”

_the_q_rel

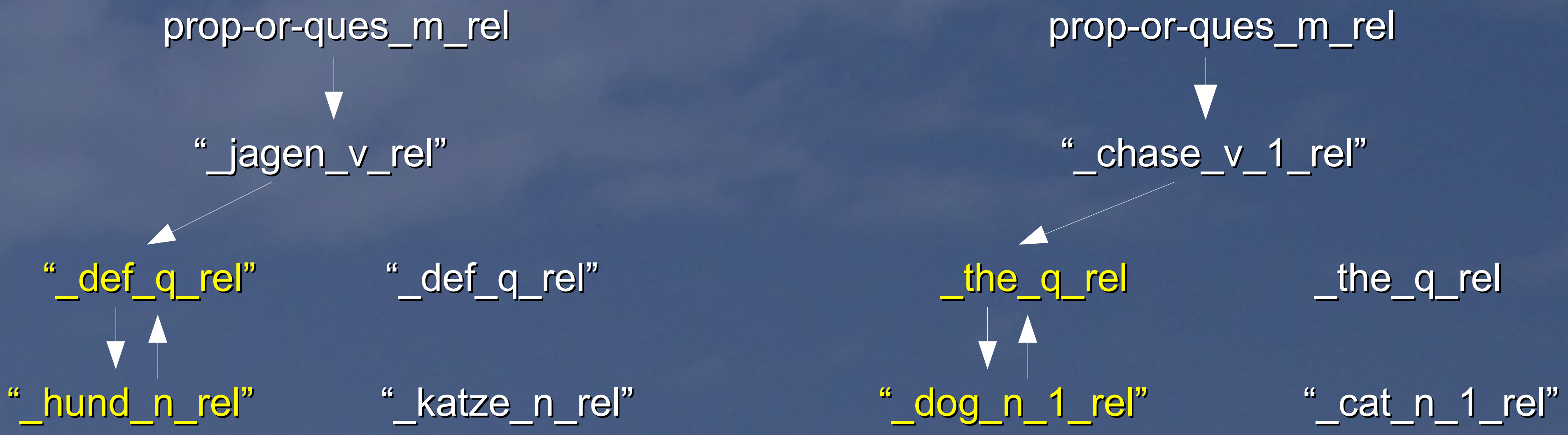
_the_q_rel

“_dog_n_1_rel”

“_cat_n_1_rel”

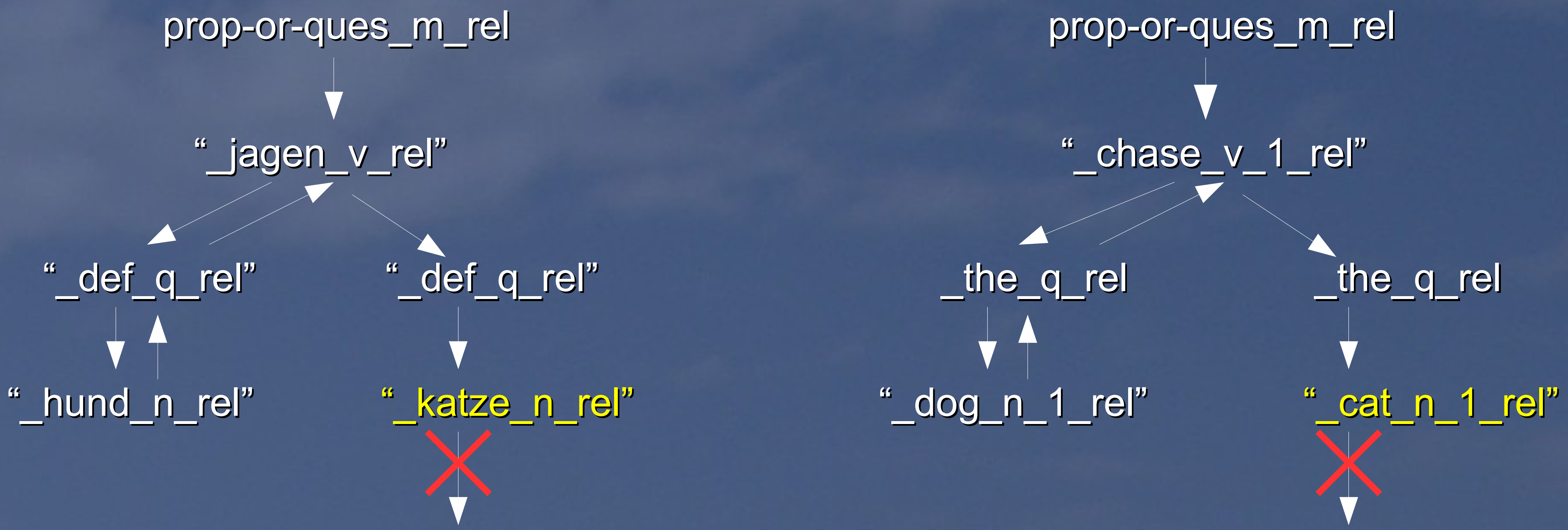
```
the_rule_0 :=monotonic_omtr &
 [ INPUT [ RELS < [ PRED _the_q_rel, LBL #1, RSTR #2, ARG0 #3 & [PERS #4, NUM #5],
                                  BODY #6 ] > ],
   OUTPUT [ RELS < [ PRED "_def_q_rel", LBL #1, RSTR #2, ARG0 #3 & [PERS #4, NUM #5],
                                  BODY #6 ] > ] ].
```

Transfer Rule Acquisition Example



```
the_rule_1 := monotonic_omtr &
  [ INPUT [ RELS < [ PRED "_dog_n_1_rel", LBL #1, ARG0 #2 & [PERS #3, NUM #4] ],
                               [ PRED _the_q_rel, LBL #5, RSTR #6, ARG0 #2, BODY #7 ] >,
                 HCONS < [qeq & HARG #6, LARG #1] > ],
    OUTPUT [ RELS < [ PRED "_def_q_rel", LBL #5, RSTR #6, ARG0 #2 & [PERS #3, NUM #4],
                                    BODY #7 ],
                                   [ PRED "_hund_n_rel", LBL #1, ARG0 #2 ] >,
                     HCONS < [qeq & HARG #6, LARG #1] >  ] ].
```

Transfer Rule Acquisition Example



prop-or-ques_m_rel

“_jagen_v_rel”

“_def_q_rel”

“_def_q_rel”

“_hund_n_rel”

“_katze_n_rel”

prop-or-ques_m_rel

“_chase_v_1_rel”

_the_q_rel

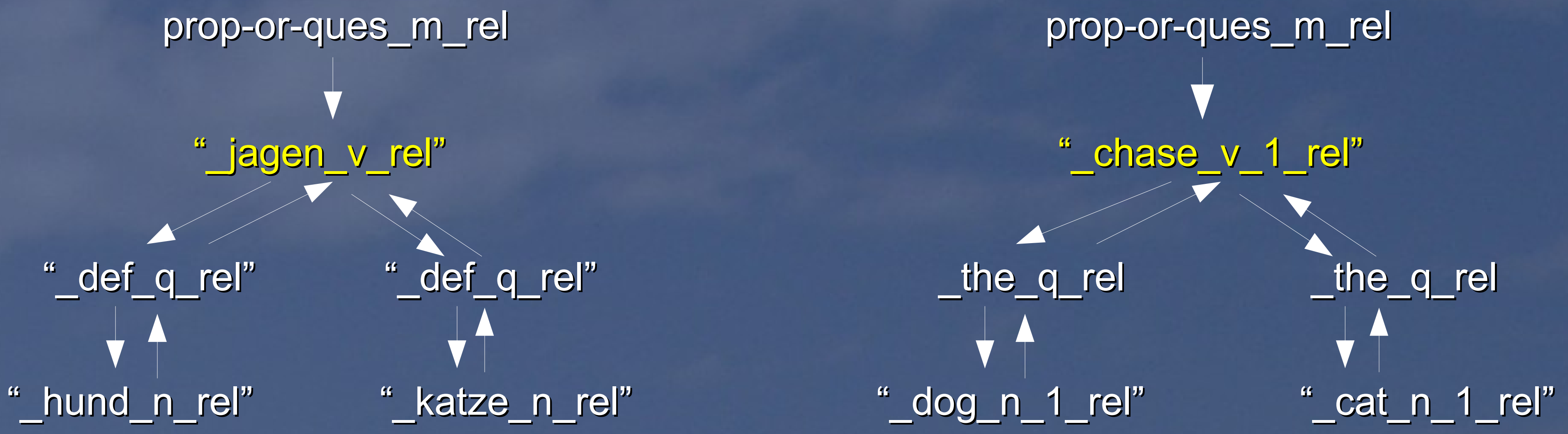
_the_q_rel

“_dog_n_1_rel”

“_cat_n_1_rel”

cat_rule_0 := monotonic_omtr &
[INPUT [RELS < [PRED "_cat_n_1_rel", LBL #1, ARG0 #2 & [PERS #3, NUM #4]] >],
OUTPUT [RELS < [PRED "_katze_n_rel", LBL #1, ARG0 #2 & [PERS #3, NUM #4]] >]].

Transfer Rule Acquisition Example



prop-or-ques_m_rel

"_jagen_v_rel"

"_def_q_rel" "_def_q_rel"

"_hund_n_rel" "_katze_n_rel"

prop-or-ques_m_rel

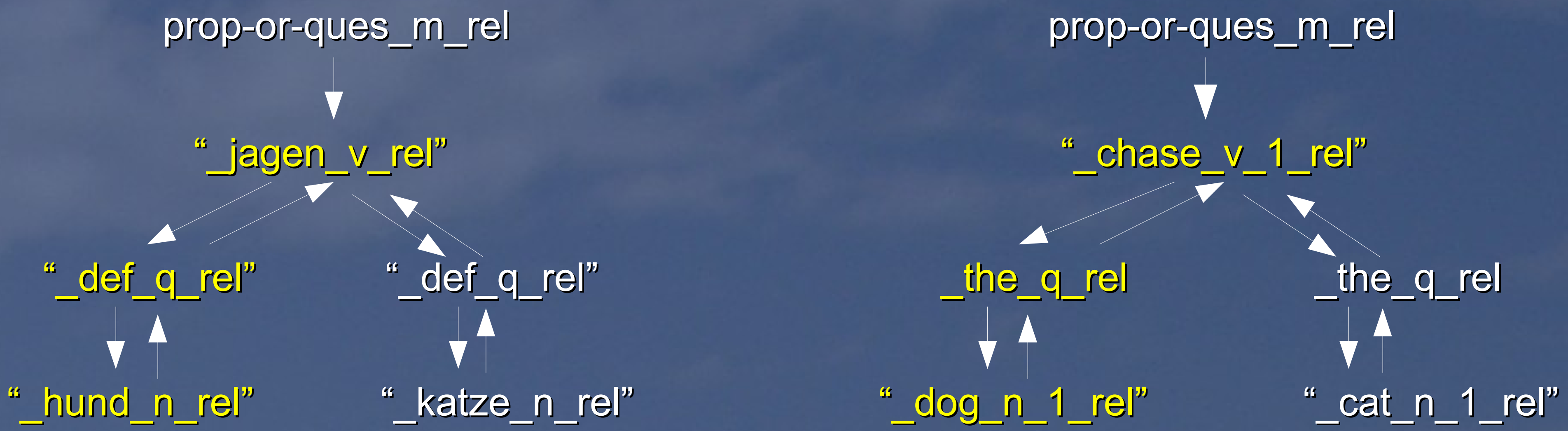
"_chase_v_1_rel"

_the_q_rel _the_q_rel

"_dog_n_1_rel" "_cat_n_1_rel"

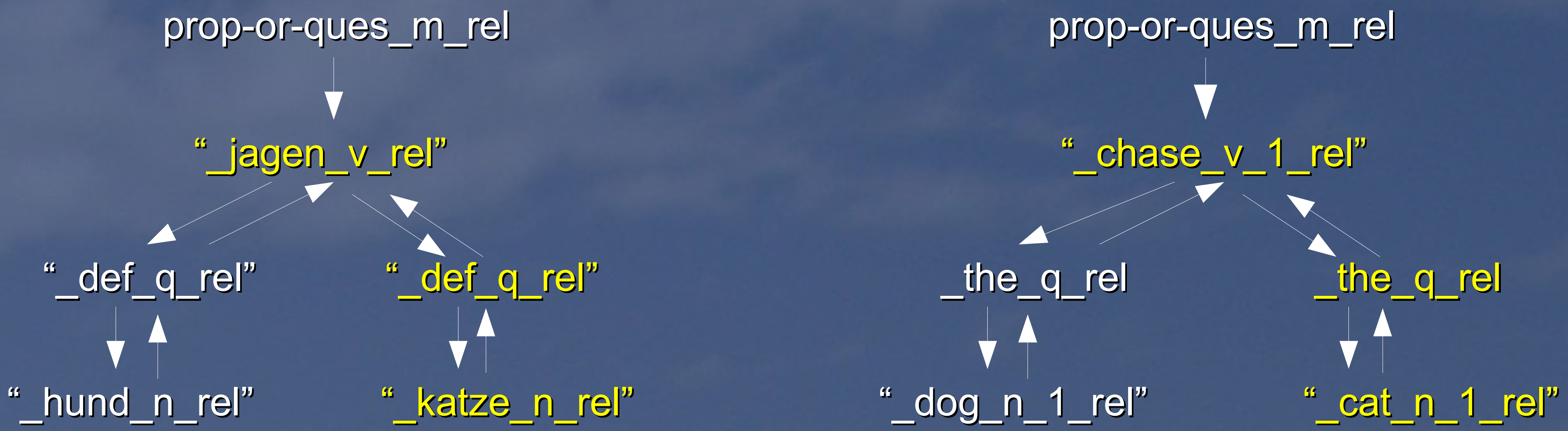
```
chase_rule_0 := monotonic_omtr &
[ INPUT [ RELS < [ PRED "_chase_v_1_rel", LBL #1, ARG0 #2 & [MOOD #3, TENSE #4],
                                ARG2 #5, ARG1 #6 ] > ],
OUTPUT [ RELS < [ PRED "_jagen_v_rel", LBL #1, ARG0 #2 & [TENSE #4, MOOD #3],
                                  ARG2 #5, ARG1 #6 ] > ] ].
```

Transfer Rule Acquisition Example



```
chase_rule_1 := monotonic_omtr &
[ INPUT [ RELS < [ PRED "_dog_n_1_rel", LBL #1, ARG0 #2 & [PERS #3, NUM #4] ],
                               [ PRED _the_q_rel, LBL #5, RSTR #6, ARG0 #2, BODY #7 ],
                               [ PRED "_chase_v_1_rel", LBL #8, ARG0 #9 & [MOOD #10, TENSE #11], ARG2 #8, ARG1 #2 ] >,
                HCONS < [qeq & HARG #6, LARG #1] > ],
  OUTPUT [ RELS < [ PRED "_jagen_v_rel", LBL #8, ARG0 #9 & [TENSE #11, MOOD #10],
                                     ARG2 #8, ARG1 #2 & [PERS #3, NUM #4] ],
                                   [ PRED "_def_q_rel", LBL #5, RSTR #6, ARG0 #2, BODY #7 ],
                                   [ PRED "_hund_n_rel", LBL #1, ARG0 #2 ] >,
                    HCONS < [qeq & HARG # 6, LARG #1] > ] ].
```

Transfer Rule Acquisition Example



prop-or-ques_m_rel

“_jagen_v_rel”

“_def_q_rel” “_def_q_rel”

“_hund_n_rel” “_katze_n_rel”

prop-or-ques_m_rel

“_chase_v_1_rel”

_the_q_rel _the_q_rel

“_dog_n_1_rel” “_cat_n_1_rel”

```
chase_rule_2 := monotonic_omtr &
[ INPUT [ RELS < [ PRED _the_q_rel, LBL #1, RSTR #2, ARG0 #3 & [PERS #4, NUM #5], BODY #6 ],
                 [ PRED "_chase_v_1_rel", LBL #7, ARG0 #8 & [MOOD #9, TENSE #10], ARG2 #3, ARG1 #11 ],
                 [ PRED "_cat_n_1_rel", LBL #12, ARG0 #3 ] >,
          HCONS < [qeq & HARG #2, LARG #12] > ],
  OUTPUT [ RELS < [ PRED "_jagen_v_rel", LBL #7, ARG0 #8 & [TENSE #10, MOOD #9],
                    ARG2 #3 & [PERS #4, NUM #5], ARG1 #11 ],
                  [ PRED "_def_q_rel", LBL #1, RSTR #2, ARG0 #3, BODY #6 ],
                  [ PRED "_katze_n_rel", LBL #12, ARG0 #3 ] >,
           HCONS < [qeq & HARG #2, LARG #12] > ] ].
```

Kinds of Transfer Rules

- Simple “lexical” rules
- Rules with multiple EPs on input and/or output side
  - Multi-word expressions / compounds
  - Phrasal translations
    - e.g., *the book I like most* vs. *my favourite book*
  - EPs together with one or more of their argument “subtrees”, e.g.,
    - *the cat eats ...* → *die Katze frisst ...* (not *isst*)
    - *... sitzt auf der Bank* → ... *sits on the bench* (not *bank*)
    - But neither complete sentences nor less interesting collocations such as verb-adjective combinations etc.

Transfer Rule Acquisition Pipeline

- Preprocessing
  - Tokenization
  - Part-of-speech tagging
  - Named entity recognition
- Parsing
- Treebanking
  - parse selection (done manually in experiments)
    - *Example for ambiguity: Das Kind jagt die Katze*
- Semantic alignment and rule extraction
  - Algorithm is language-independent
- Construction of transfer rule set

Construction of Transfer Rule Set

- Quality control
  - Learned rules are rejected unless complete alignment achieved
- Internal order of rule set:
  - Sort rules by number of input EPs (“specific rules first” strategy for increased idiomaticity)
  - Then sort by rules' extraction frequency (in order to eliminate noise)
    - Examples of noise:
      - *Wer...* → *what group...* (loose translation)
      - *Das Kind jagt die Katze* (ambiguity)
      - Other errors at the various levels (parsing, alignment, ...)

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Evaluation

- Closed evaluation on MRS Test Suite (107 sentences)
  - All sentences contributing to rule set were translated correctly (plus additional results due to ambiguity or syntactic variation from the generator)
- Evaluation on unseen data (but lexical items and constructions had been seen; 79 sentences)
  - As above, except for 2 sentences that were translated incorrectly (could be tracked to treebanking error)
- Evaluation on CLEF corpus (QA data; about 1600 sentences)
  - No clean results yet :(

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Outlook

- Evaluation on larger corpora and other languages
  - Quantitative
    - Coverage, BLEU score etc.
  - Qualitative
    - Which phenomena are difficult/easy?
    - Compare with SMT (“division of labour”)
- Automatic parse selection
  - Goal: eliminate manual treebanking step
- Build hybrid systems
  - Back-off to SMT when out of coverage
  - Provide high-confidence phrase pairs to SMT phrase table

Outlook

- Rule set experiments
  - Maximum size?
  - What are interesting collocations?
  - Generalise rules
    - HPSG types
    - Semantic classes (information from ontologies)
  - Stochastification(?)
- Learn more rules:
  - Extract at least phrase translation rules if sentences cannot be aligned completely
  - Acquire rules from dictionaries etc.
- Use in application-based evaluation

One Last Example from Google Translate ...

Input:

Danke, dass ihr meinem Talk so aufmerksam gefolgt seid ohne einzuschlafen

Zuletzt nehme ich noch gerne eure Fragen und Anmerkungen entgegen

Output:

Thank you, that you talk to my attention are followed without einzuschlafen

Recently, I still like your questions and comments contrary to