

Grammar-Based Processing and Re-Usable Hybrid MT

— An Experience Report in the Wilderness —

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(Machine Translation Marathon – May 16, 2008)

Grammar-Based Processing for Machine Translation?

*on the west - bank it there lay DecimalErsatz setre almost at
the side of each other .* [Naïve Norwegian – English SMT]

*Do not want to go so far, is Besstrondrundhø an excellent
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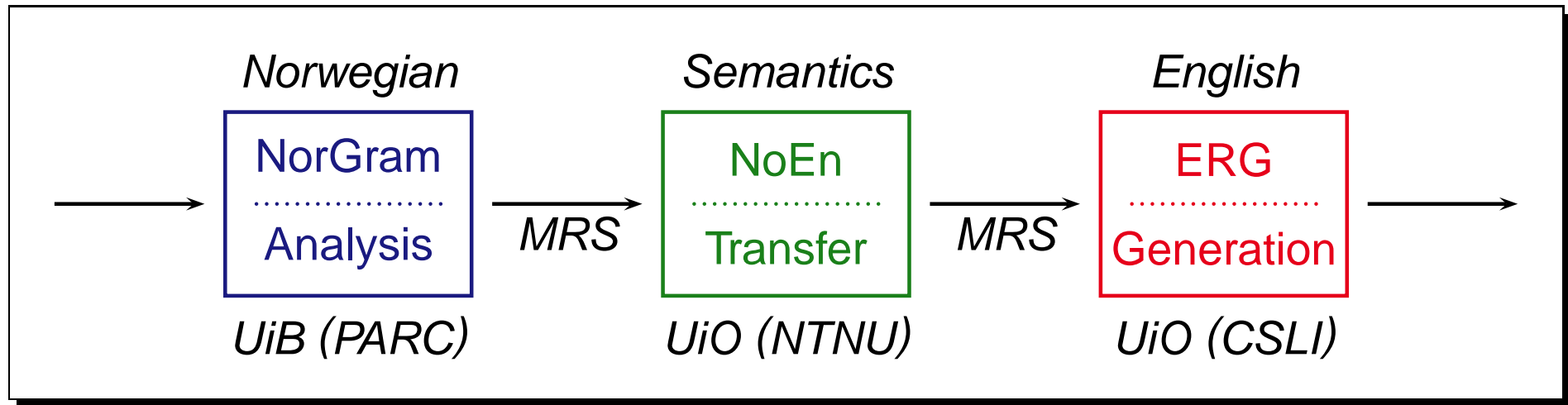
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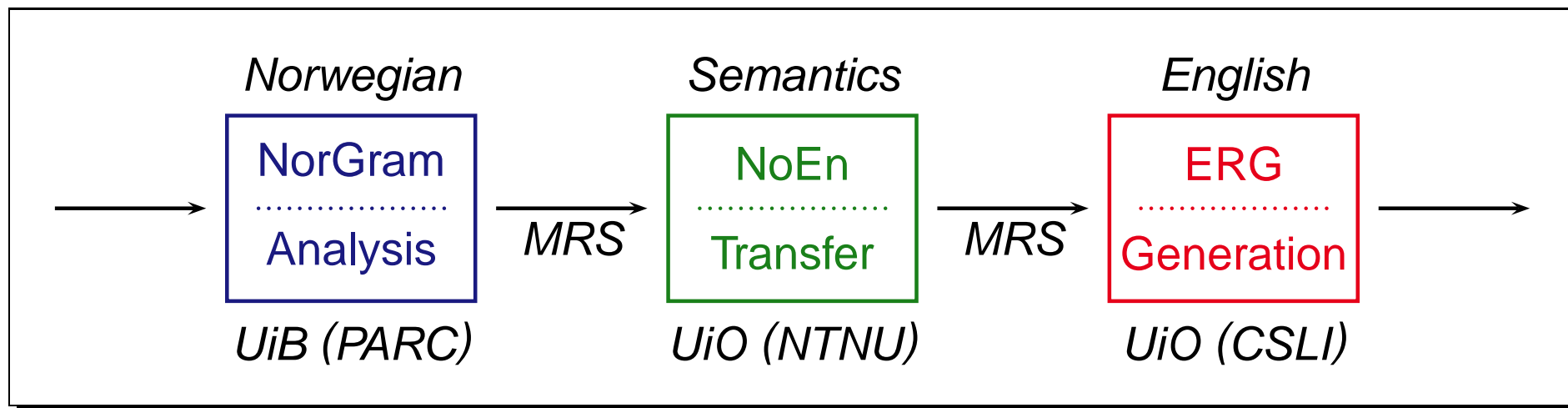
Broad Progress in Computational Linguistics

- Precise, broad-coverage grammars now available (e.g. LFG & HPSG);
- linguistic grammar relates strings to syntactic *and* semantic analyses;
- grammar (pretty much) guarantees wellformedness of system outputs;
- combination with stochastic processes to rank and select hypotheses.

Old-Fashioned MT: The Norwegian LOGON Project



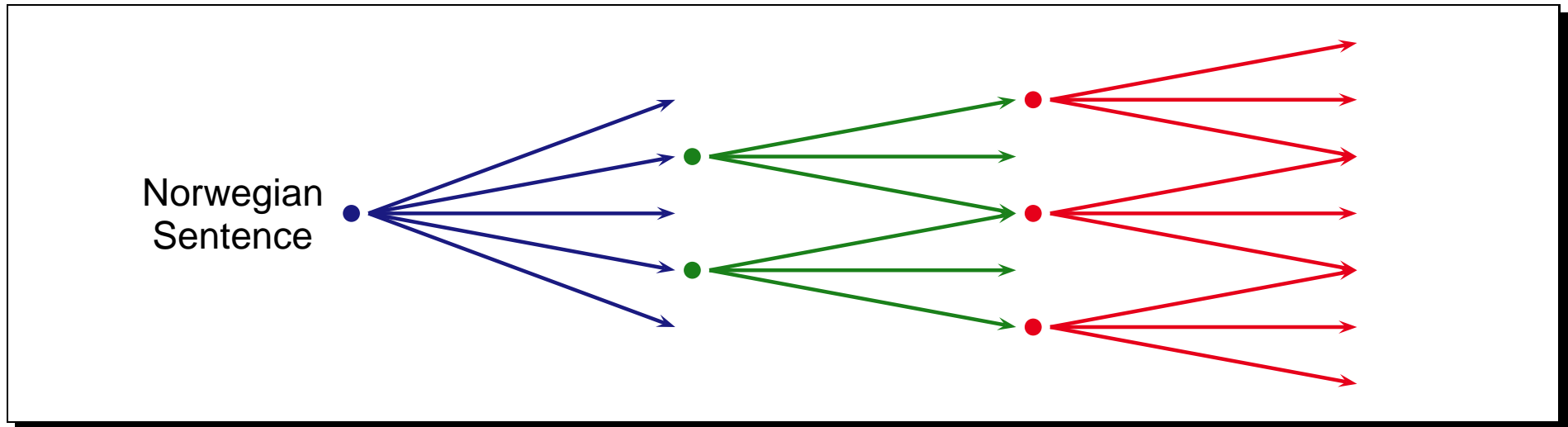
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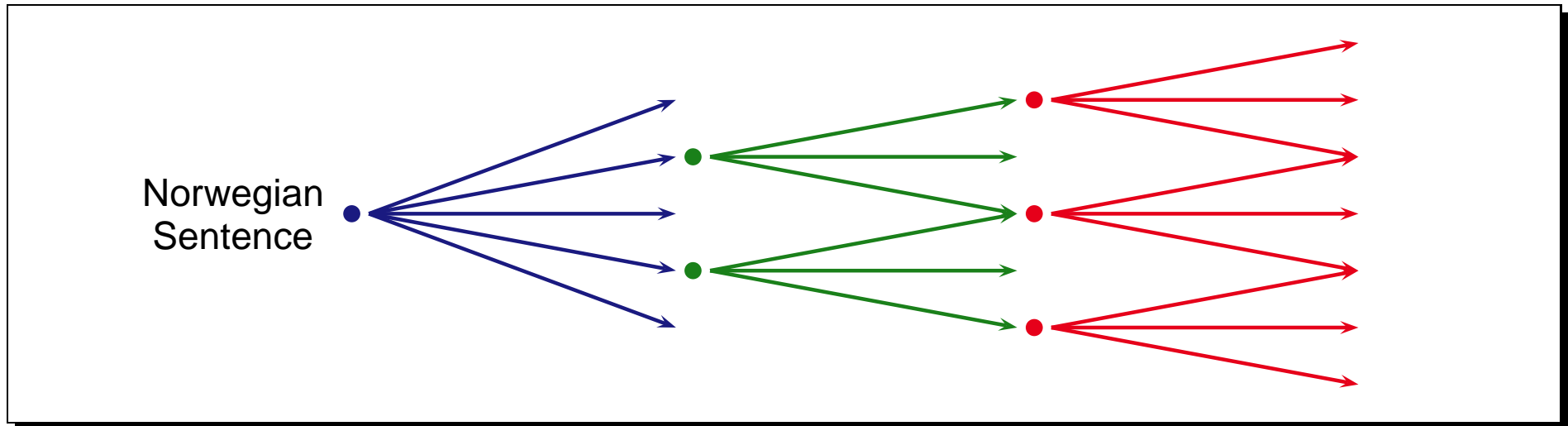
Some LOGON Highlights

- Re-usable, mono-lingual precision grammars as linguistic back-bone;
 - abstract from language-internal idiosyncrasies by semantic transfer;
- most likely unique in combination of LFG and HPSG in working system.

Ambiguity Management: Stochastic Processes



Ambiguity Management: Stochastic Processes



Stochastic Elements in LOGON

- At each stage, rank alternate hypotheses according to local probability;
 - discriminative re-ranking: normalize and combine scores to re-order;
- hybrid MT: linguistic back-bone, combined with advanced statistics.

For Example: Various Sources of Ambiguity

- < Den andre veien mot Bergen er kort. --- 12 x 30 x 25 = 25
- > The other path towards Bergen is short. {0.58} (1:1:0).
- > The other road towards Bergen is short. {0.56} (1:0:0).
- > The second road towards Bergen is short. {0.55} (2:0:0).
- > That other path towards Bergen is a card. {0.54} (0:1:0).
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- > The second path towards Bergen is short. {0.51} (2:1:0).
- > The other road against Bergen is short. {0.48} (1:2:0).
- > The second road against Bergen is short. {0.48} (2:2:0).
- ...
- > Short is the other street towards Bergen. {0.33} (1:4:0).
- > Short is the second street towards Bergen. {0.33} (2:4:0).
- ...

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- > Th
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Scraped Off the Internet

the road to the other bergen is short .

The other road to Bergen is short.

Den other roads against Boron Gene are short.

Other one autobahn against Mountains am abrupt.

Project Organization — A Few Facts

Organizational

- ~~All but one university in Norway participate: Oslo, Bergen, Trondheim;~~
- received about 10 crowns from each Norwegian tax payer; 2003 – 2007.

Scope & Domain

- Functional core demonstrator NO – EN (limited domain and vocabulary);
- support to the regions: facilitate the translation of tourism-related texts.

Existing Resources at Project On-Set

- NorGram (ParGram): Norwegian LFG, since 1999 (Dyvik, Rosén; UiB);
- ERG (DELPH-IN): broad-coverage English HPSG (Flickinger; Stanford).

Main Development Corpora

Original Development Corpus ('tur')

- 104 sentences, picked from DNT brochure by NorGram developers;
- three project-internal translations; average length 10.5 : 12.9 words.

Jotunheimen, Preikestolen, Turglede (JHPSTG)

- Lauritzen, Per Roger (2001): *På tur i Jotunheimen*. (four booklets);
- one original, published translation; two commissioned translations;
- augmented with a few smaller texts; two commissioned translations;
- Norwegian: 4062 sentences (44079 words); English: 10927 (134973).

Some LOGON Sample Translations (Version 0.9)

1 *Velkommen til Jotunheimen!*

Welcome to Jotunheimen.

1037 *På vestbredden lå det der tre setre nesten ved siden av hverandre.*

On the west bank, 3 mountain pastures lay there almost beside each other.

1048 *Vil du ikke gå så langt, er Besstrondrundhø et utmerket alternativ.*

If you don't want to go so far, Besstrondrundhø is an excellent alternative.

1376 *Den toppen er et fint turmål om du bor på Bessheim eller Gjendesheim.*

That summit, a nice trip tongue is if you stay at Bessheim or Gjendesheim.

Minimal Recursion Semantics — By Example

The new serviced cabin opens on Sundays.

$$\langle h_1, \{ h_1:\text{proposition_m}(h_2), h_3:\text{_open_v_inchoative}(e_1, x_1), h_4:\text{def_q}(x_1, h_5, h_6), h_7:\text{_cabin_n}(x_1), h_7:\text{_new_a}(x_1), h_7:\text{_service_v}(e_2, u_1, x_1), h_3:\text{temp_loc}(e_1, x_2), h_8:\text{proper_q}(x_2, h_9, h_{10}), h_{11}:\text{dofw_n}(x_2, \text{SUNDAY}) \}, \{ h_2 =_q h_3, h_6 =_q h_7, h_{10} =_q h_{11} \} \rangle$$

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Background (Copestake et al., 1996, 2003, & 2005)

- Family of flat, underspecified semantics (including UDRS, CLLS, et al.);
- non-recursive composition: predicates, bindings, and scope constraints;
- logical-form representation of ‘who did what to whom’ → normalization;
- large, MRS-enabled grammars available for at least seven languages.

Norwegian Analysis — NorGram

The Grammar

- Actively developed at UiB since 1998; Helge Dyvik and Victoria Rosén;
- part of ParGram consortium → Xerox Linguistic Environment (XLE);
- traditionally heretic: some divergence in feature inventory; s-projection;
- large, semi-manual lexicon, though previously not focused on coverage.

Adaptation for LOGON

- Add MRS projection in co-description spirit; not defining grammaticality;
- MRS elements primarily projected off the f-structure, where possible;
- post-XLE processing: accumulation of bags and some scope relations.

The MRS Transfer Formalism

Background

- *Semantic transfer* as successive rewriting of meaning representation;
- transfer rule: replacement of SL MRS fragment with TL correspondence;
- + complex, non-monotonic transformations; works well with *flat* structures;
- + good handle on most translational correspondences *and* divergences;
- resource-sensitive process: rule ordering; reversibility not guaranteed.

Realization

- General-purpose, unification-based rewrite system on MRS structures;
- allow non-determinism (ambiguity), but tight control in transfer grammar;
- sets of rules; manual ordering of rules and sets relative to each other.

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$$\langle _ , \{ _ \text{tur_n}(x_1) \}, \{ \} \rangle : \langle _ , \{ h_0\text{:g\aa_v}(e_0, x_0, x_1) \}, \{ \} \rangle$$
$$\rightarrow \langle _ , \{ h_0\text{:take_v_1}(e_0, x_0, x_1) \}, \{ \} \rangle$$

- Ge ... ures;
- allow non-determinism (ambiguity), but tight control in transfer grammar;
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English Generation — ERG

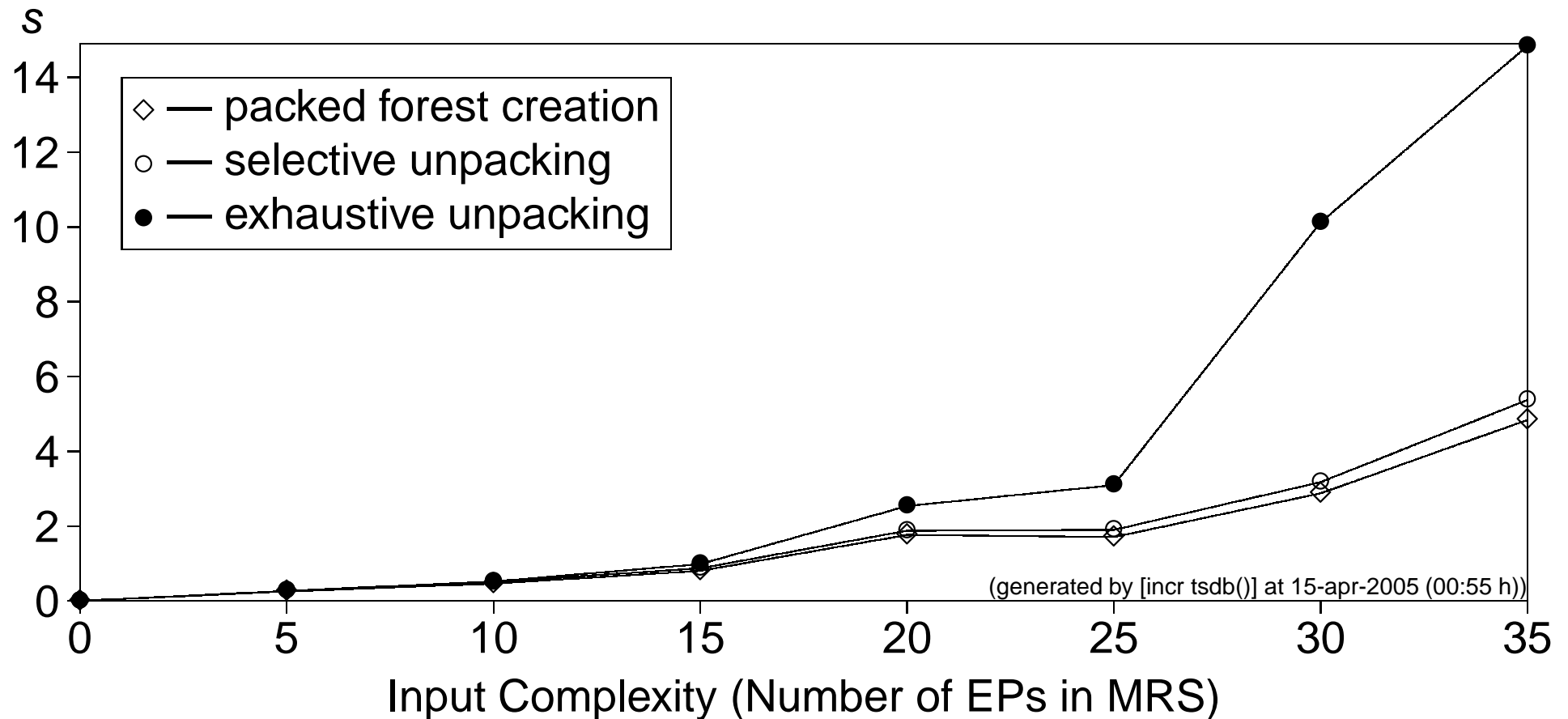
The Grammar

- LinGO English Resource Grammar (Dan Flickinger et al., since 1993);
 - general-purpose HPSG; domain-specific lexica (some 32,000 lexemes);
 - LOGON vocabulary addition and fine-tuning → 95 per cent coverage;
 - manual inspection and treebanking → up to ten percent ‘false’ coverage;
- same resource is used centrally in multiple parallel projects (non-MT).

The Generator

- Standard LKB chart generator (Kay 1996) and (Carroll et al. 1999);
- + subsumption-based ambiguity packing at edge level; adjoin into forest;
- + MaxEnt realization ranking; selective unpacking of *correct* n-best list.

Polynomial Time (Practical) Generation



→ **Average Time for 15-Word Sentences around One Second**

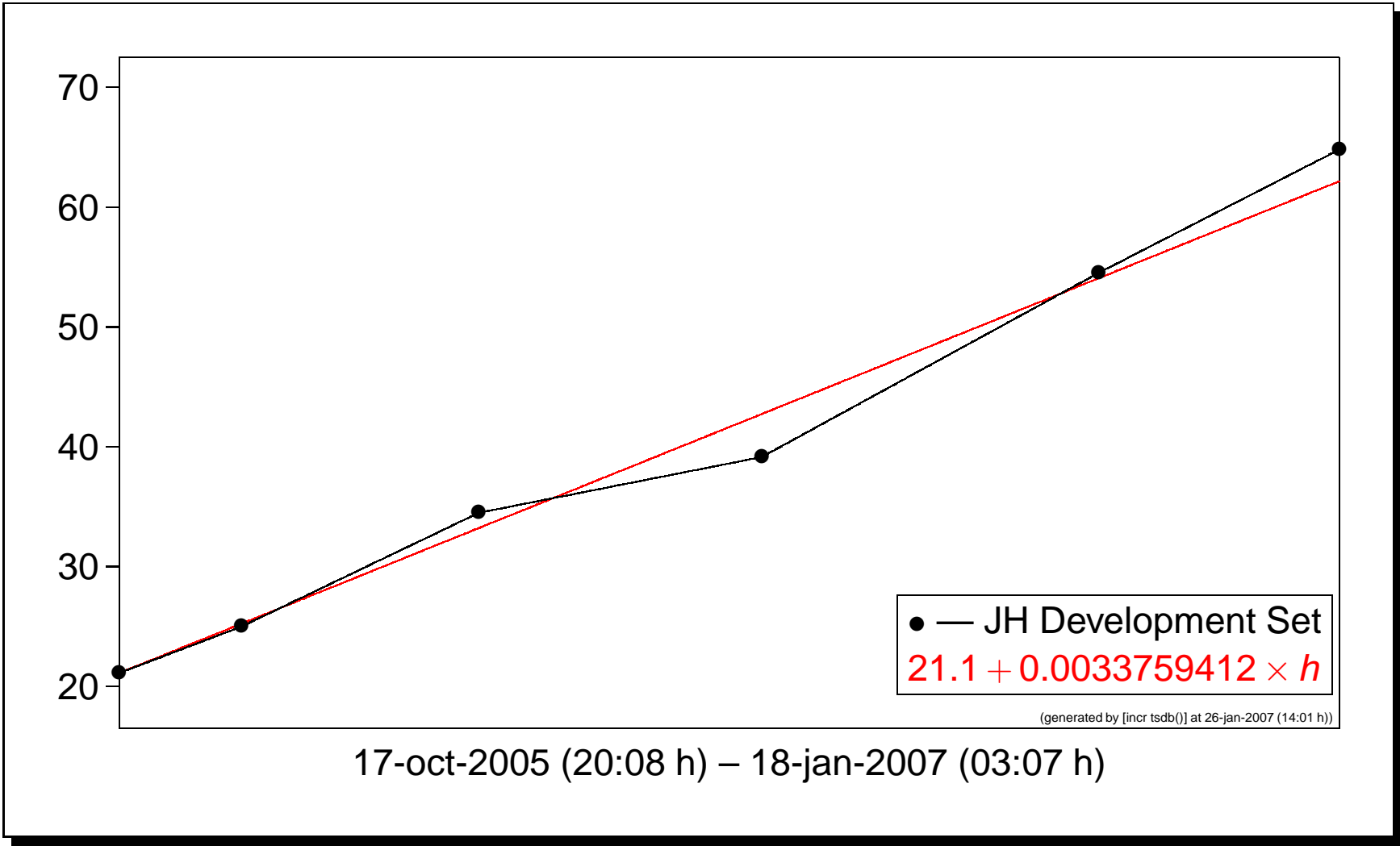
LOGON 'Current' State of Play — Facts and Figures

- August 2003 – January 2007, six active developers, ~170 person months;
→ end-to-end: $0.83 \times 0.92 \times 0.85 = 65\%$ (71% vs. 56% on held-out sets).

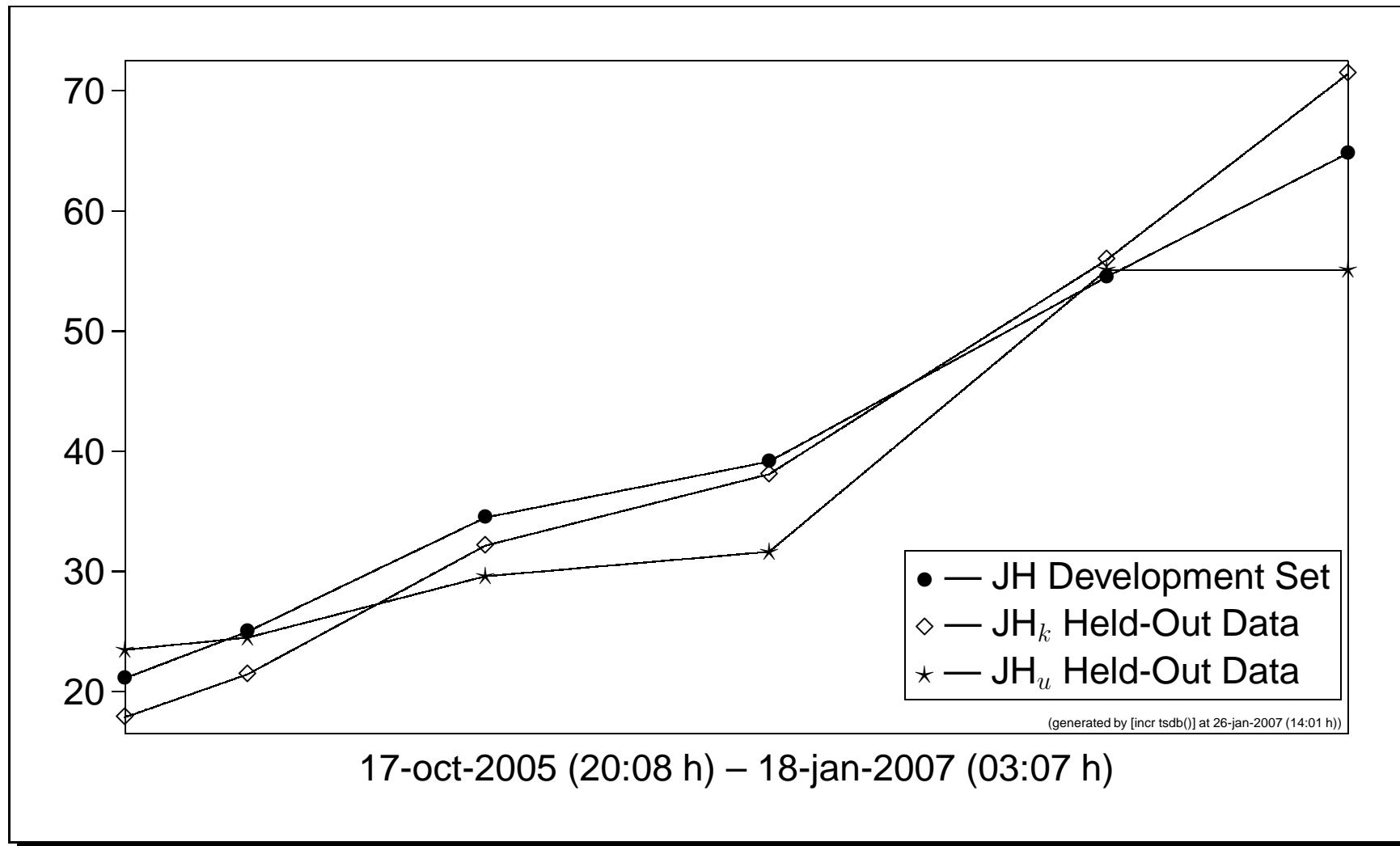
Linguistic Resources & Stochastic Models

- NorGram (Dyvik et al.): 8⁺ years; new MRS projection → 67.5 + 15.1 %;
+ adaption of discriminant treebanking to LFG; native XLE parse selection.
- LinGO ERG (Flickinger et al.): 13⁺ years; domain vocabulary → 94.3 %;
+ structural MaxEnt plus BNC language model (Velldal & Oepen, 2006).
- 7627 hand-built transfer rules, 9222 from bi-lingual dictionary → 92.4 %;
+ LM of dependency tuples: MRS 'fluency' by similarity to domain MRSs.

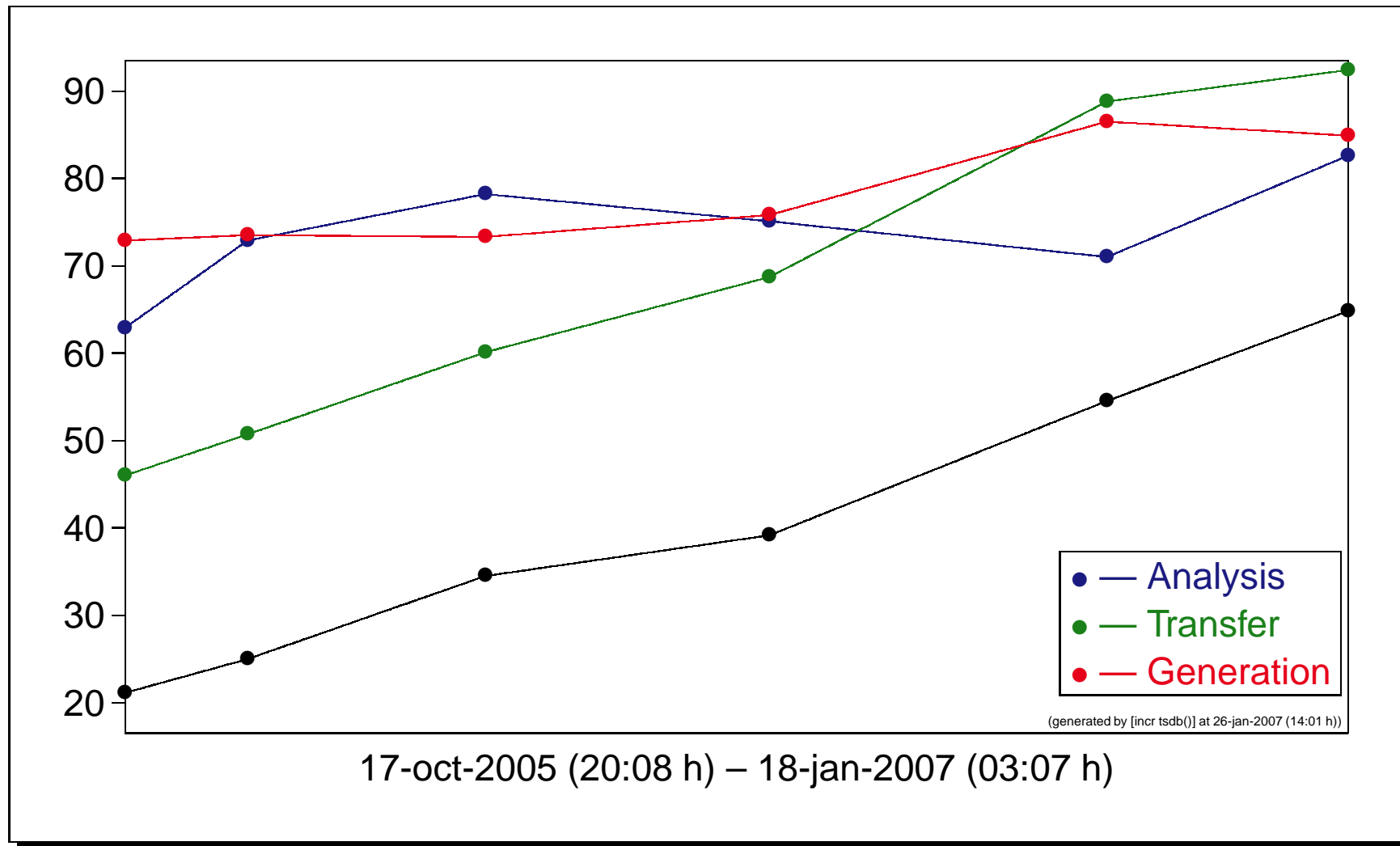
The Quest for Coverage: End-to-End Throughput



Comparing Development and Held-Out Data



Evolution of Individual Components (on JH)

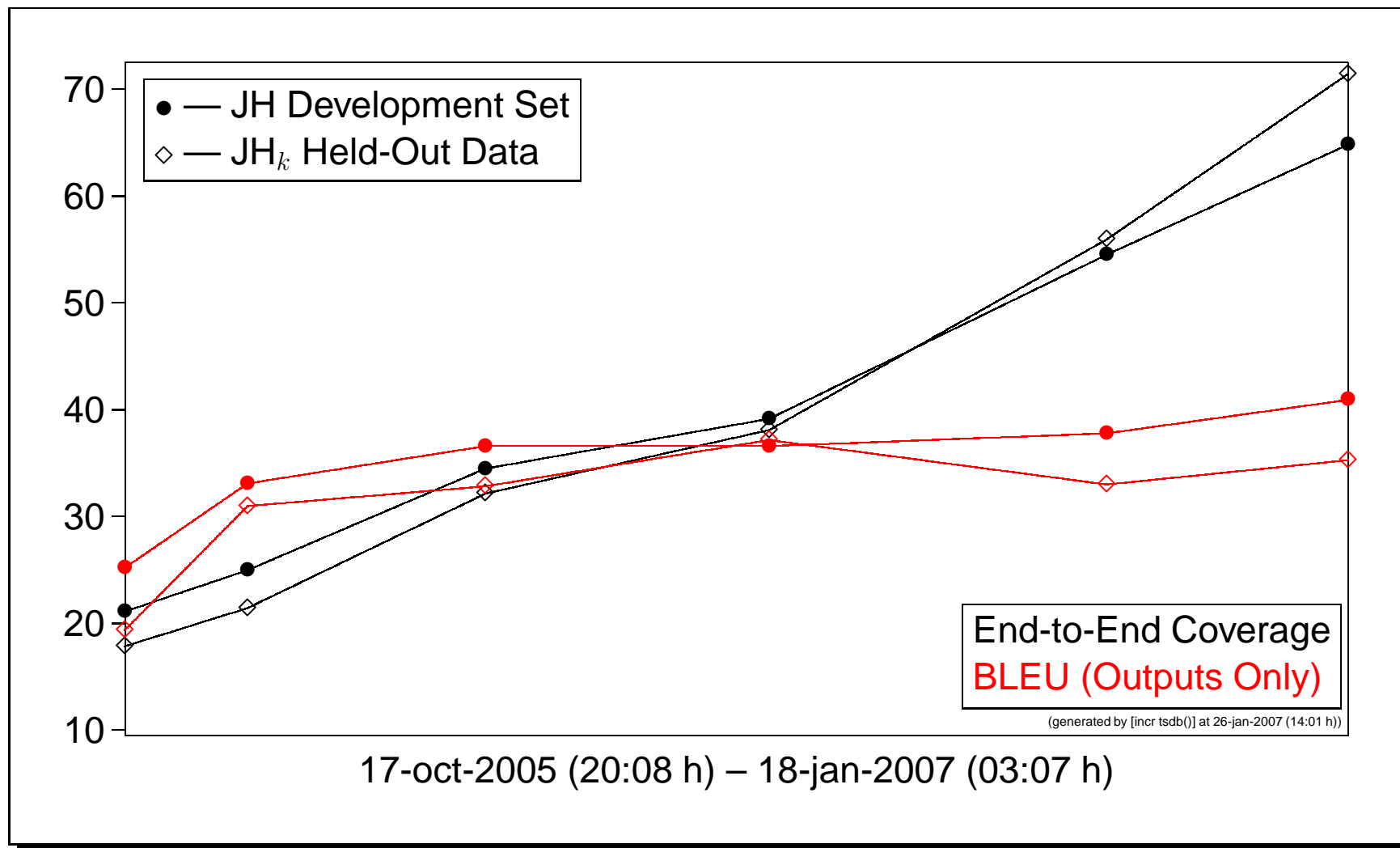


End-to-End Coverage vs. Input Length

'gold/logon/jh' Coverage Profile						
Aggregate	total items ‡	positive items ‡	word string ϕ	distinct analyses ϕ	total results ‡	overall coverage %
$35 \leq i\text{-length} < 60$	32	32	39.94	0.00	0	0.0
$30 \leq i\text{-length} < 35$	56	56	31.48	198.00	1	1.8
$25 \leq i\text{-length} < 30$	137	137	26.82	1180.73	11	8.0
$20 \leq i\text{-length} < 25$	235	235	21.87	2543.04	50	21.3
$15 \leq i\text{-length} < 20$	369	369	16.93	667.42	173	46.9
$10 \leq i\text{-length} < 15$	416	416	12.11	321.63	302	72.6
$5 \leq i\text{-length} < 10$	454	454	6.68	36.87	418	92.1
$0 \leq i\text{-length} < 5$	447	447	2.13	3.81	436	97.5
Total	2146	2146	12.64	266.00	1391	64.8

(generated by [incr tsdb()] at 26-jan-2007 (14:04 h))

One (Allegedly) Objective Measure (on JH)



A Human Judgment Study (on Unseen Test Data)

Experimental Setup

- 250 held-out sentences, eight judges (English native, Norwegian fluent);
- **fidelity** ‘to what degree is the original meaning preserved’ (0 to 3);
- **fluency** ‘to what degree is the translation natural sounding’ (0 to 3);
- custom web interface; judges required to comment on values below 3.

	OA	SMT	first	top	judge
fidelity	1.28	1.59	1.83	1.94	2.05
fluency	1.27	1.31	1.62	1.69	1.79

End-to-End Re-ranking: Features (Very Briefly)

The Core: Per-Component Scores

- **Parse Selection** Unnormalized MaxEnt score (i.e. sum of weights);
 - **Transfer Outputs** n-gram perplexity against 'semantic' model (LM);
 - **Realization Ranking** unnormalized MaxEnt score (sum of weights).
- Using unnormalized scores to prevent 'vote dilution' across branches.

Additional Properties (Tried So Far)

- **Language Model** tri-gram model, trained on BNC plus domain corpus;
- **Lexical Translation Probabilities** GIZA⁺⁺ word-to-word alignment;
- **Distortion** re-ordering, based on MRS EPs and sub-string pointers;
- **Harmony** string length and MRS size proportions: $|e|/|f|$ and $|E|/|F|$.

MaxEnt Re-Ranking: Preliminary Results

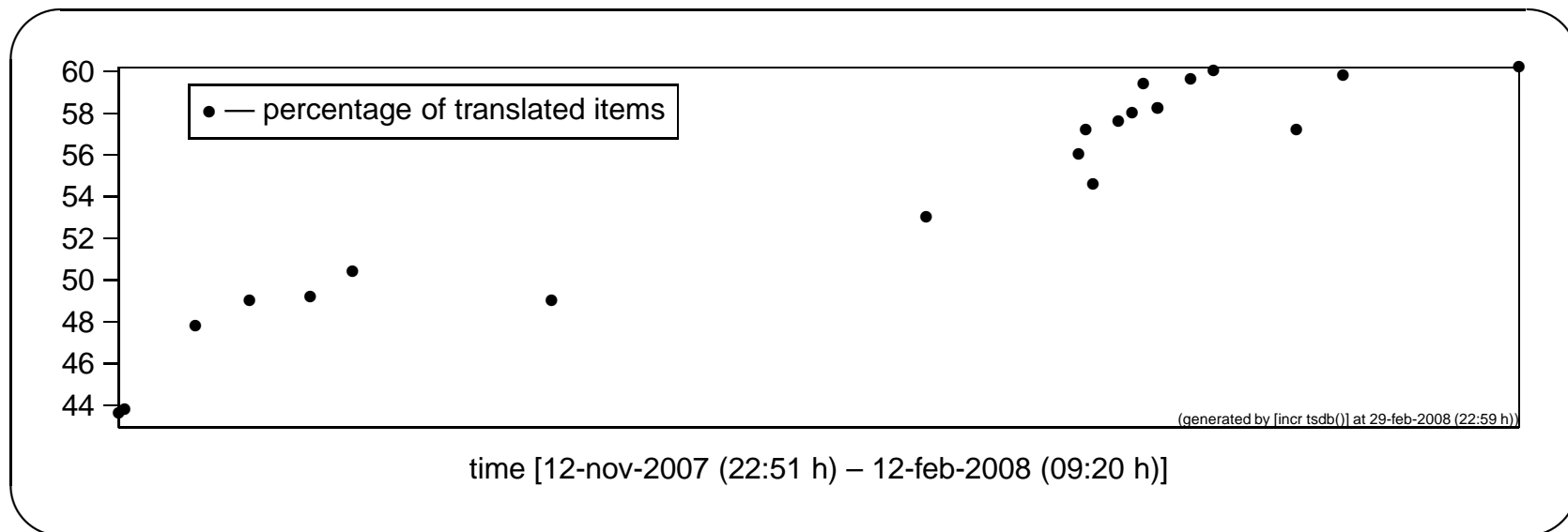
- Log-linear re-ranker, trained on development corpus (Och & Ney, 2002);
- use NEVA (sentence-level BLEU) to rank and 'label' candidate outputs.

data	#	words	coverage	strings
JH_d	2146	12.6	64.8%	266
JH_t	182	11.7	63.2%	114.6

data	#	chance	first	LL	top	judge
JH_d	1391	34.18	40.95	44.10	49.89	—
JH_t	115	30.84	35.67	38.92	45.74	46.32

On Scalability — A Limited Experiment

- Post-LOGON, try to double vocabulary size (5,000 → 10,000 lexemes);
- short pilot: about eight person months (kEUR 100); one new developer;
- web harvest ~270k tokens NO (~430k EN); general tourism information;
- mechanic, partiallyautomized lexicon extensions to all three grammars.



Preliminary Conclusions — Outlook

LOGON Results To Date

- General-purpose NLP components feasible as symbolic MT back-bone;
- when successful end-to-end, high-quality output(s) typically available;
- improved stochastic models needed for disambiguation and re-ranking;
- (way) too much unpacking; need ability to explore larger search space.

Towards Re-Usable (MT) Technology

- All LOGON modules (but the XLE) available publicly as open-source;
- baby JA – EN system built in one afternoon; now developed at NICT;
- automatic DE – EN transfer acquisition (DFKI); Matrix-Based MT (UW).

On-Line: <http://www.emmtee.net/> **and** <http://www.delph-in.net/>

A (Not Quite) Half-Baked Vision

End-to-End Ambiguity Factoring (Packing)

- Chart parsers and generators internally manipulate a *packed forest*;
→ weighted *and-or graph*: exhaustive search computationally tractable;
+ selective unpacking: exact inference, avoid exponential combinatorics;
– currently no (interesting) packing at transfer level; breadth-first rewriting;
- MRS structurally similar to many predicate – argument representations.

Re-Usable Technology for (Transfer-Based) MT

- ? Disjunctive MRS(-like) graph structures as weighted and – or graph;
- ? weighted rewriting process (aka semantic transfer) as graph search;
- ? cascaded weighted and – or search: generalized (open-source) toolkit.

Based on Research and Contributions of

Dorothee Beermann, Francis Bond, John Carroll,
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Gunn Inger Lyse, Jan Tore Lønning, Paul Meurer,
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