Computer Aided Translation

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Why Machine Translation?

Assimilation — reader initiates translation, wants to know content

- user is tolerant of inferior quality
- focus of majority of research

Communication — participants don't speak same language, rely on translation

- users can ask questions, when something is unclear
- chat room translations, hand-held devices
- often combined with speech recognition

Dissemination — publisher wants to make content available in other languages

- high demands for quality
- currently almost exclusively done by human translators

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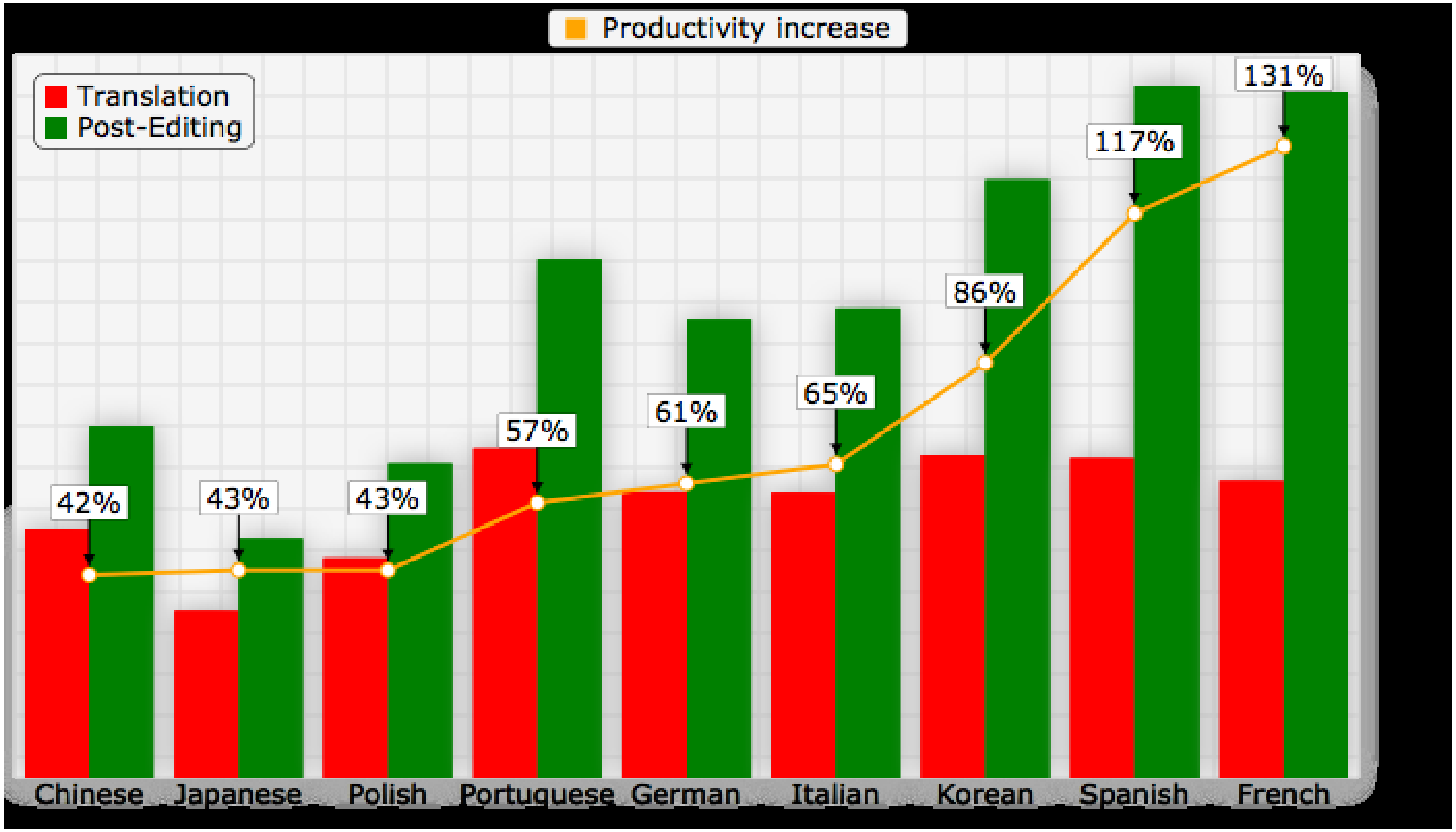
Goal: Helping Human Translators

If you can't beat them, join them.

$\rightarrow$ How can machine translation help human translators?

Post-Editing Machine Translation



(source: Autodesk)

MT Quality and Productivity

System	BLEU	Training Sentences	Training Words (English)
MT1	30.37	14,700k	385m
MT2	30.08	7,350k	192m
MT3	29.60	3,675k	96m
MT4	29.16	1,837k	48m
MT5	28.61	918k	24m
MT6	27.89	459k	12m
MT7	26.93	230k	6.0m
MT8	26.14	115k	3.0m
MT9	24.85	57k	1.5m

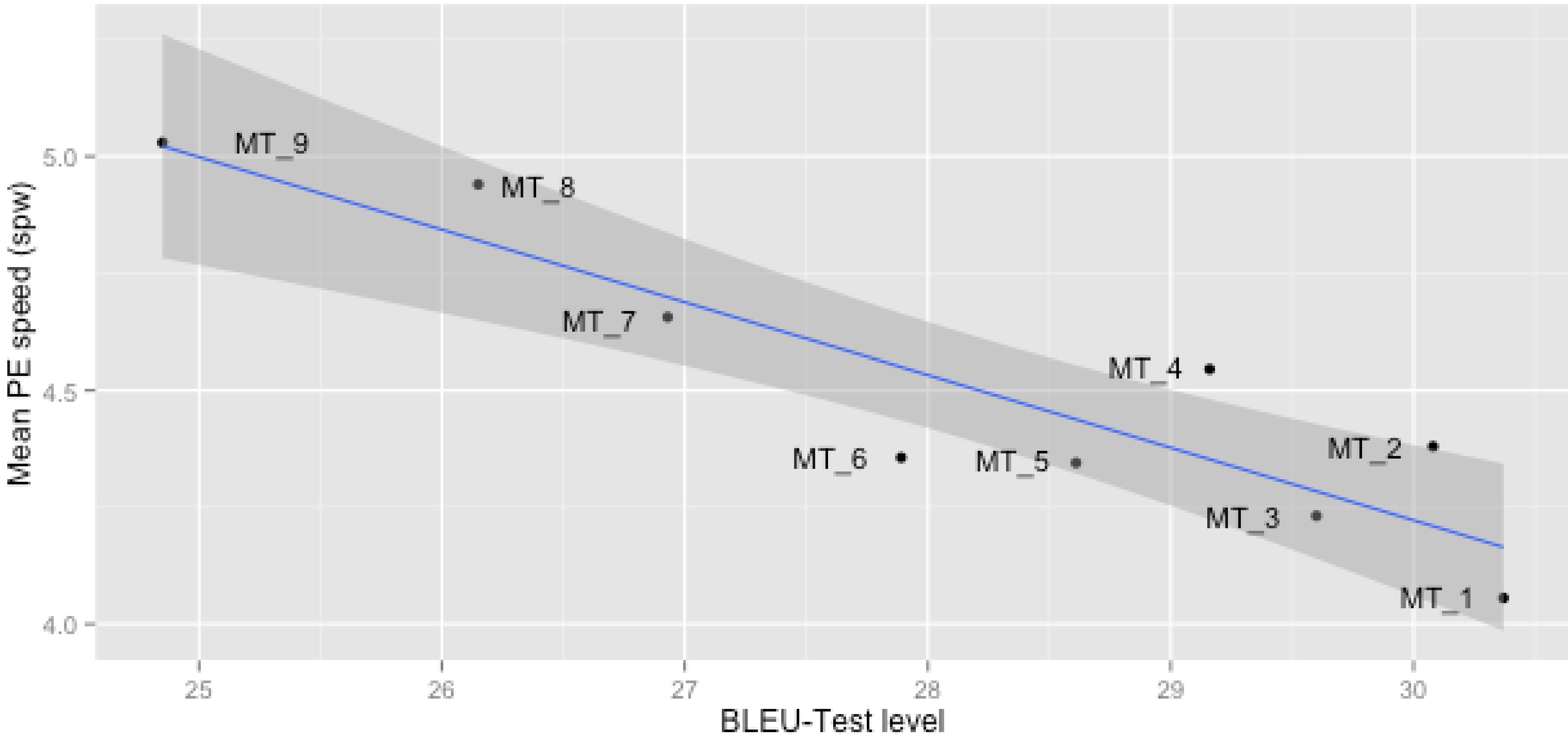
- Same type of system (Spanish–English, phrase-based, Moses)
- Trained on varying amounts of data [Sanchez-Torron and Koehn, AMTA 2016]

MT Quality and Productivity

System	BLEU	Training Sentences	Training Words (English)	Post-Editing Speed
MT1	30.37	14,700k	385m	4.06 sec/word
MT2	30.08	7,350k	192m	4.38 sec/word
MT3	29.60	3,675k	96m	4.23 sec/word
MT4	29.16	1,837k	48m	4.54 sec/word
MT5	28.61	918k	24m	4.35 sec/word
MT6	27.89	459k	12m	4.36 sec/word
MT7	26.93	230k	6.0m	4.66 sec/word
MT8	26.14	115k	3.0m	4.94 sec/word
MT9	24.85	57k	1.5m	5.03 sec/word

- User study with professional translators
- Correlation between BLEU and post-editing speed?

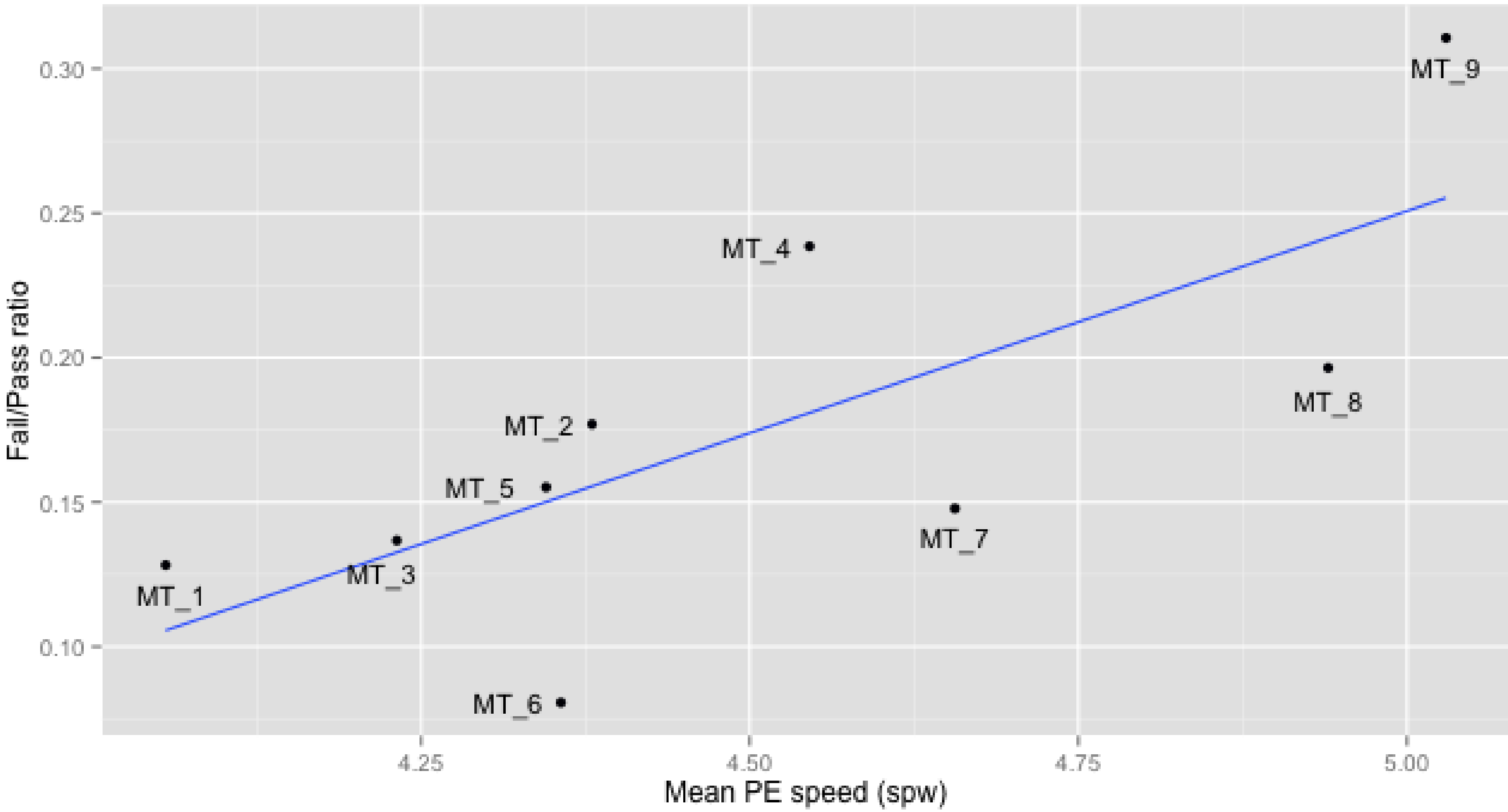
MT Quality and Productivity



BLEU against PE speed and regression line with 95% confidence bounds

+1 BLEU ↔ decrease in PE time of ~0.16 sec/word, or 3-4% speed-up

MT Quality and PE Quality



better MT $\leftrightarrow$ fewer post-editing errors

Translator Variability

	HTER	Edit Rate	PE speed (spw)	MQM Score	Fail	Pass
TR1	44.79	2.29	4.57	98.65	10	124
TR2	42.76	3.33	4.14	97.13	23	102
TR3	34.18	2.05	3.25	96.50	26	106
TR4	49.90	3.52	2.98	98.10	17	120
TR5	54.28	4.72	4.68	97.45	17	119
TR6	37.14	2.78	**2.86**	97.43	24	113
TR7	39.18	2.23	**6.36**	97.92	18	112
TR8	50.77	7.63	6.29	97.20	19	117
TR9	39.21	2.81	5.45	96.48	22	113

- Higher variability between translators than between MT systems

Overview

- **Interactivity**
- Choices
- User Studies
- Confidence
- Adaptation

Interactivity

- Traditional professional translation approaches
  - translation from scratch
  - post-editing translation memory match
  - post-editing machine translation output

- More interactive collaboration between machine and professional?

Interactive Machine Translation

Input Sentence

Er hat seit Monaten geplant, im November einen Vortrag in Baltimore zu halten.

Professional Translator

|

Interactive Machine Translation

Input Sentence

Er hat seit Monaten geplant, im November einen Vortrag in Baltimore zu halten.

Professional Translator

| He

Interactive Machine Translation

Input Sentence

Er hat seit Monaten geplant, im November einen Vortrag in Baltimore zu halten.

Professional Translator

He | has

Interactive Machine Translation

Input Sentence

Er hat seit Monaten geplant, im November einen Vortrag in Baltimore zu halten.

Professional Translator

He has | for months

Interactive Machine Translation

Input Sentence

Er hat seit Monaten geplant, im November einen Vortrag in Baltimore zu halten.

Professional Translator

He planned |

Interactive Machine Translation

Input Sentence

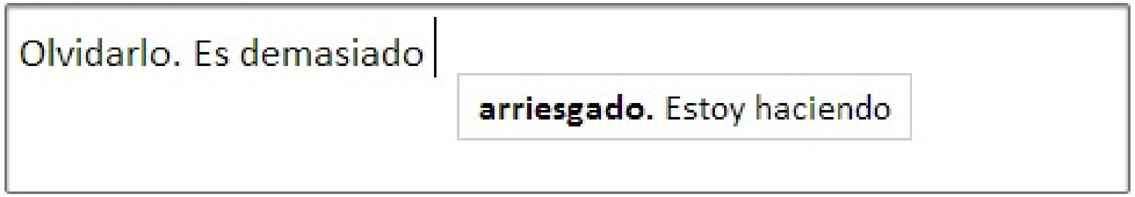
Er hat seit Monaten geplant, im November einen Vortrag in Baltimore zu halten.

Professional Translator

He planned | for months

Visualization

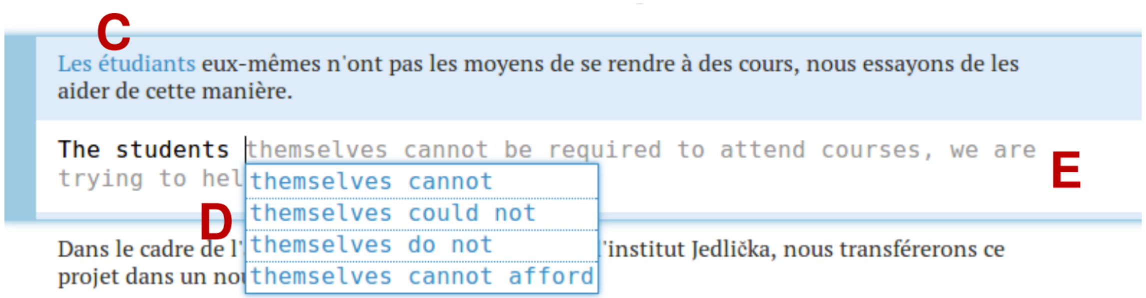
- Show n next words



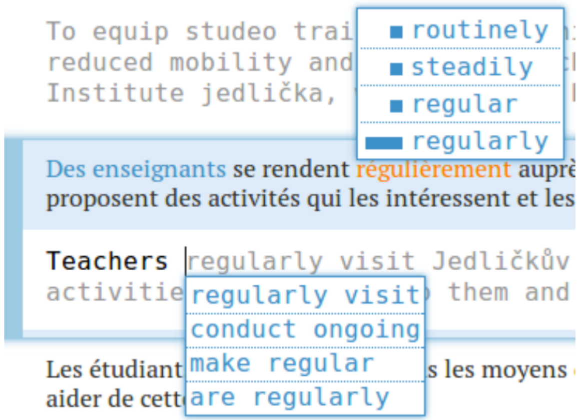
- Show rest of sentence

Spence Green's Lilt System

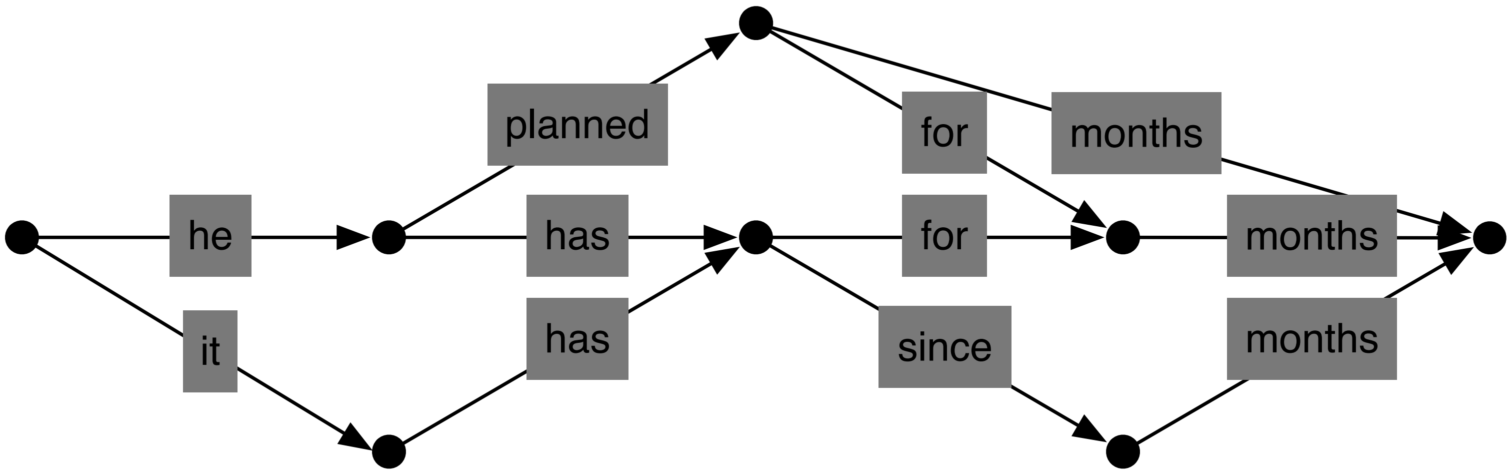
- Show alternate translation predictions



- Show alternate translations predictions with probabilities

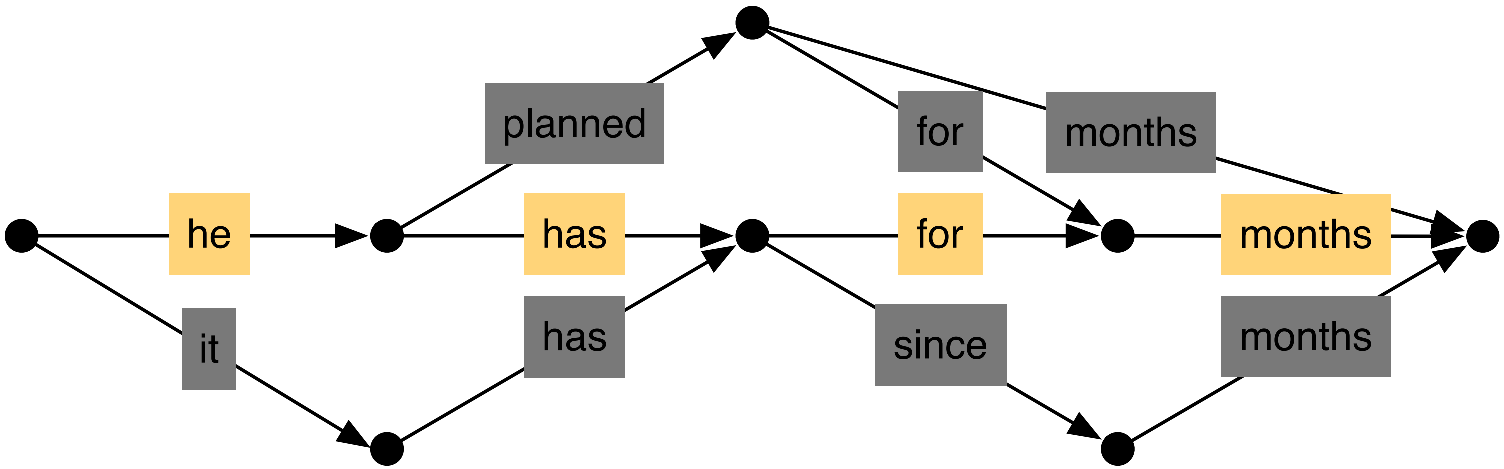


Prediction from Search Graph



Search for best translation creates a graph of possible translations

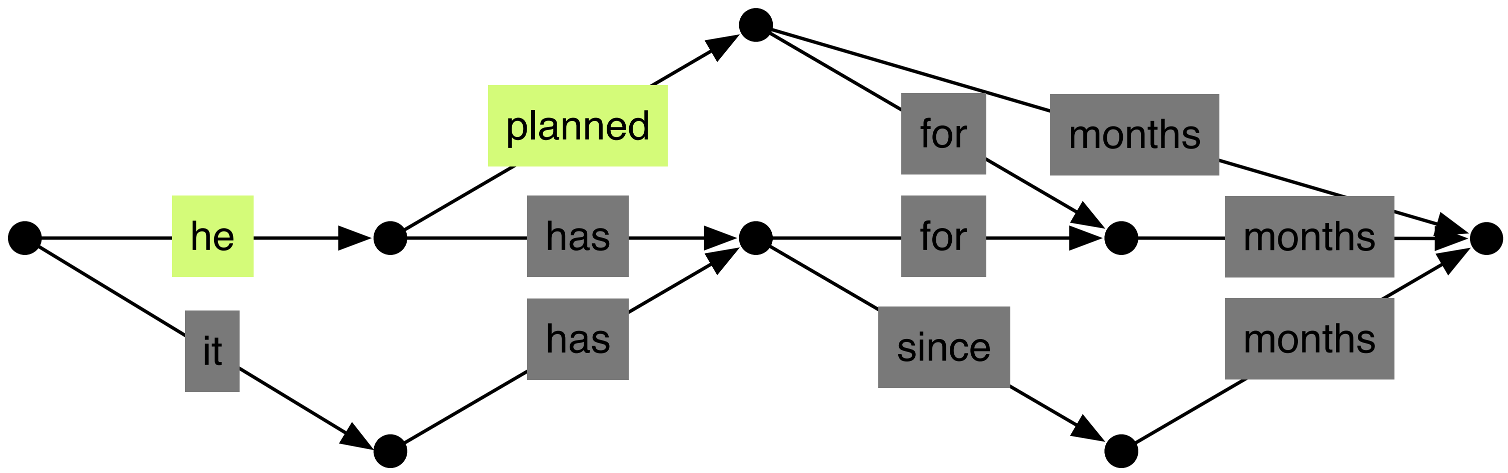
Prediction from Search Graph



One path in the graph is the best (according to the model)

This path is suggested to the user

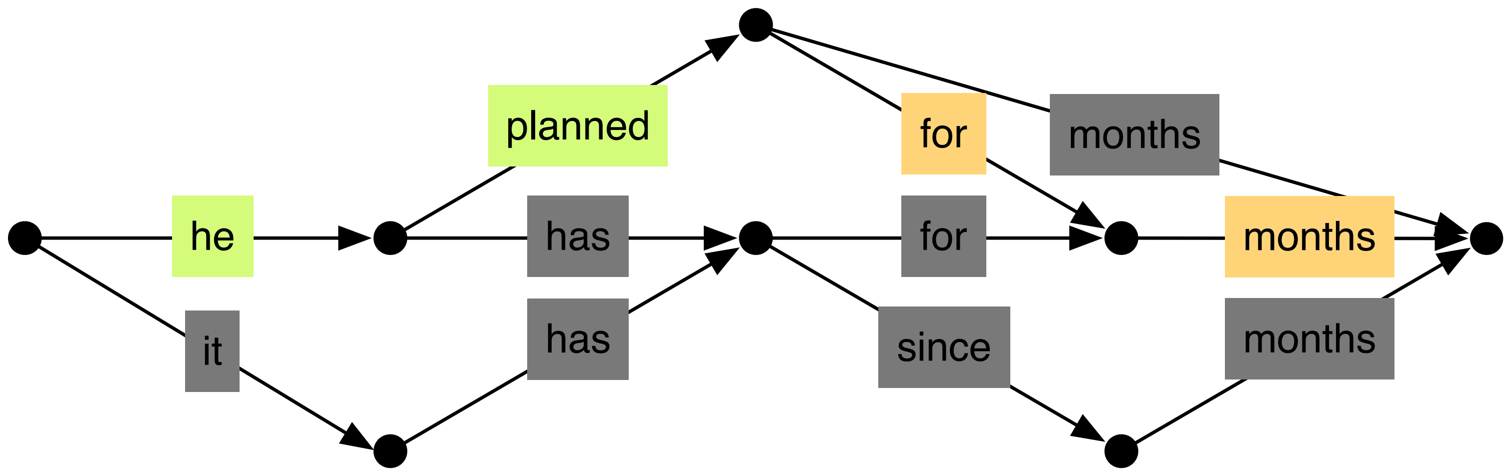
Prediction from Search Graph



The user may enter a different translation for the first words

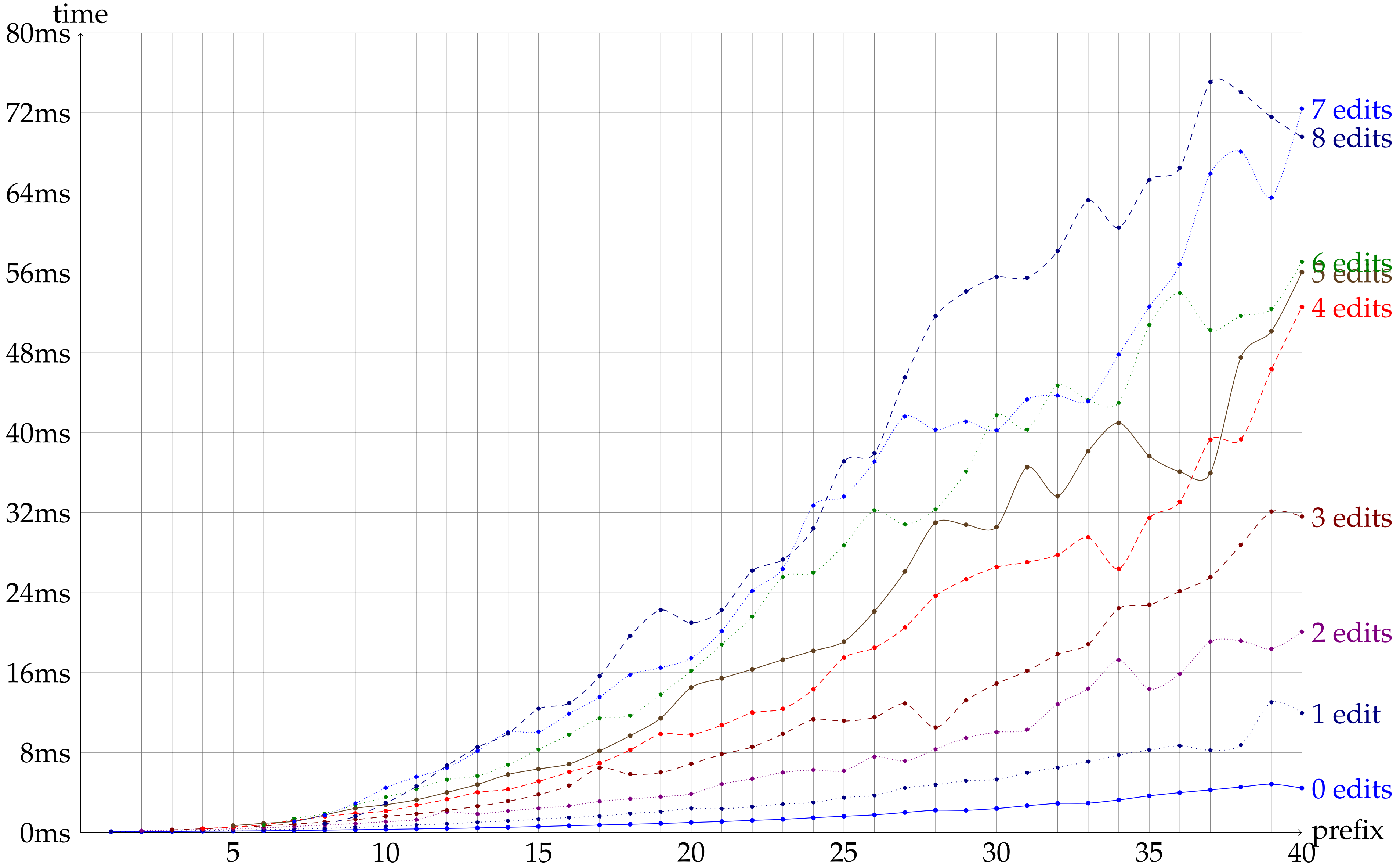
We have to find it in the graph

Prediction from Search Graph



We can predict the optimal completion (according to the model)

Run Time


time
80ms
72ms
64ms
56ms
48ms
40ms
32ms
24ms
16ms
8ms
0ms
5
10
15
20
25
30
35
40
prefix
7 edits
8 edits
6 edits
5 edits
4 edits
3 edits
2 edits
1 edit
0 edits

Word Alignment Visualization

Input Sentence

Er hat seit Monaten geplant, im November einen Vortrag in Baltimore zu halten.

Professional Translator

He planned for months to give a lecture in Baltimore | in

Word Alignment Visualization

Input Sentence

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Shading off Translated Material

Input Sentence

Er hat seit Monaten geplant, im November einen Vortrag in Baltimore zu halten .

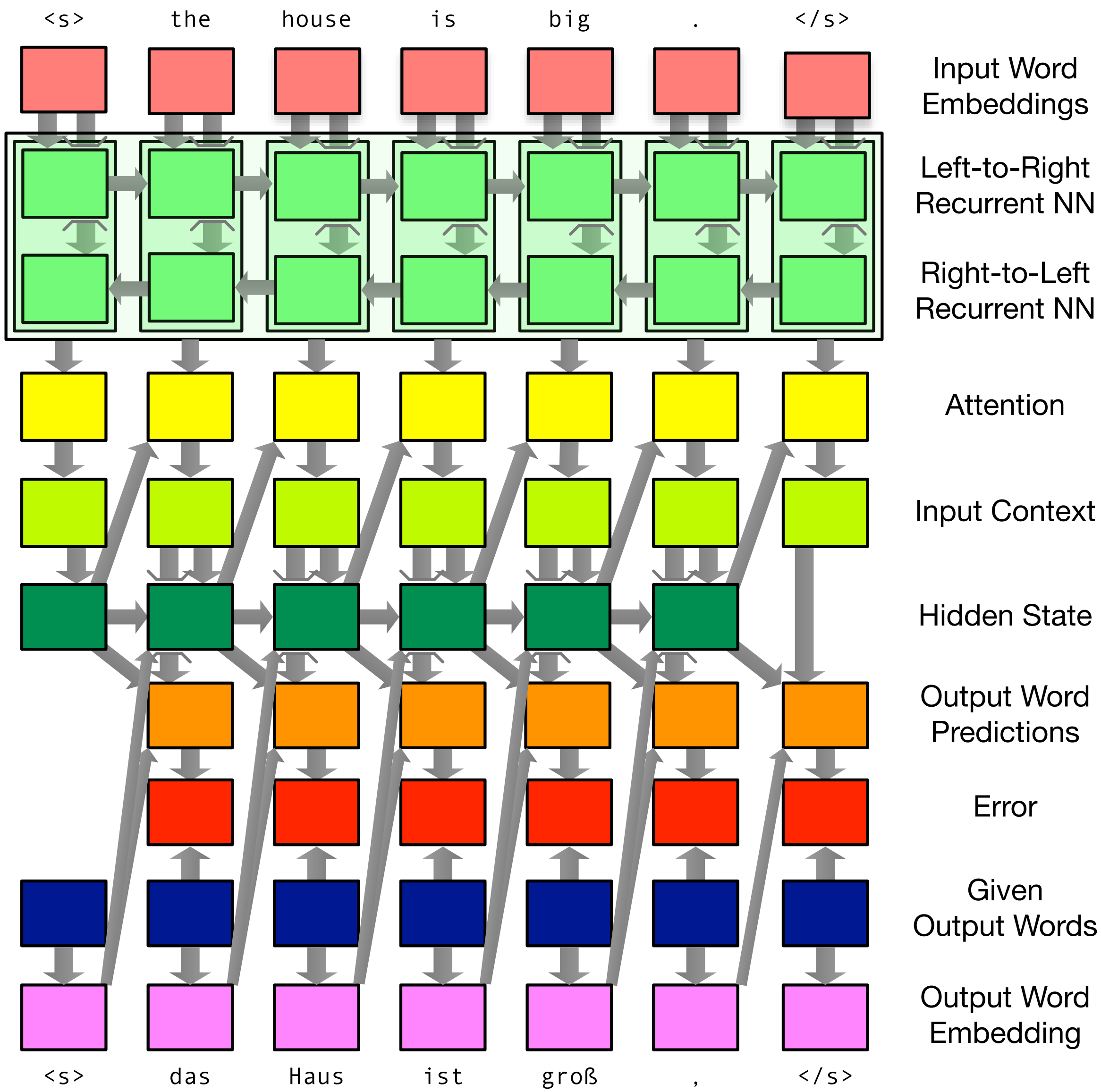
Professional Translator

He planned for months to give a lecture in Baltimore | in

Some Observations

- How can we do this?
  - word alignments by-product of matching against search braph
  - automatic word alignments (as used in training)
- User feedback
  - users like interactive machine translation
  - ... but they may be slower than with post-editing machine translation
  - user like mouse-over word alignment highlighting
  - user do not like at-cursor word alignment highlighting

Neural Interactive Translation Prediction



Neural MT: Sequential Prediction

- The model produces words in sequence

$$p(\text{output}_t | \{\text{output}_1, \cdots, \text{output}_{t-1}\}, \vec{\text{input}}) = g(\hat{\text{output}}_{t-1}, \text{context}_t, \text{hidden}_t)$$

- Translation prediction: feed in user prefix

Example

Input: *Das Unternehmen sagte, dass es in diesem Monat mit Bewerbungsgesprächen beginnen wird und die Mitarbeiterzahl von Oktober bis Dezember steigt.*

	Correct	Prediction	Prediction probability distribution
✓	the	the	**the (99.2%)**
✓	company	company	**company (90.9%)**, firm (7.6%)
✓	said	said	**said (98.9%)**
✓	it	it	**it (42.6%)**, this (14.0%), that (13.1%), job (2.0%), the (1.7%), ...
✓	will	will	**will (77.5%)**, is (4.5%), started (2.5%), 's (2.0%), starts (1.8%), ...
✓	start	start	**start (49.6%)**, begin (46.7%)
	inter@@	job	job (16.1%), application (6.1%), en@@ (5.2%), out (4.8%), ...
✘	viewing	state	state (32.4%), related (5.8%), **viewing (3.4%)**, min@@ (2.0%), ...
✘	applicants	talks	talks (61.6%), interviews (6.4%), discussions (6.2%), ...
✓	this	this	**this (88.1%)**, so (1.9%), later (1.8%), that (1.1%)
✓	month	month	**month (99.4%)**
✘	,	and	and (90.8%), **, (7.7%)**
✘	with	and	and (42.6%), increasing (24.5%), rising (6.3%), **with (5.1%)**, ...
✓	staff	staff	**staff (22.8%)**, the (19.5%), employees (6.3%), employee (5.0%), ...
✘	levels	numbers	numbers (69.0%), **levels (3.3%)**, increasing (3.2%), ...
✘	rising	increasing	increasing (40.1%), **rising (35.3%)**, climbing (4.4%), rise (3.4%), ...
✓	from	from	**from (97.4%)**
✓	October	October	**October (81.3%)**, Oc@@ (12.8%), oc@@ (2.9%), Oct (1.2%)
✘	through	to	to (73.2%), **through (15.6%)**, until (8.7%)
✓	December	December	**December (85.6%)**, Dec (8.0%), to (5.1%)
✓	.	.	**. (97.5%)**

Knowles and Koehn [AMTA 2016]

- Better prediction accuracy, even when systems have same BLEU score (state-of-the-art German-English systems, compared to search graph matching)

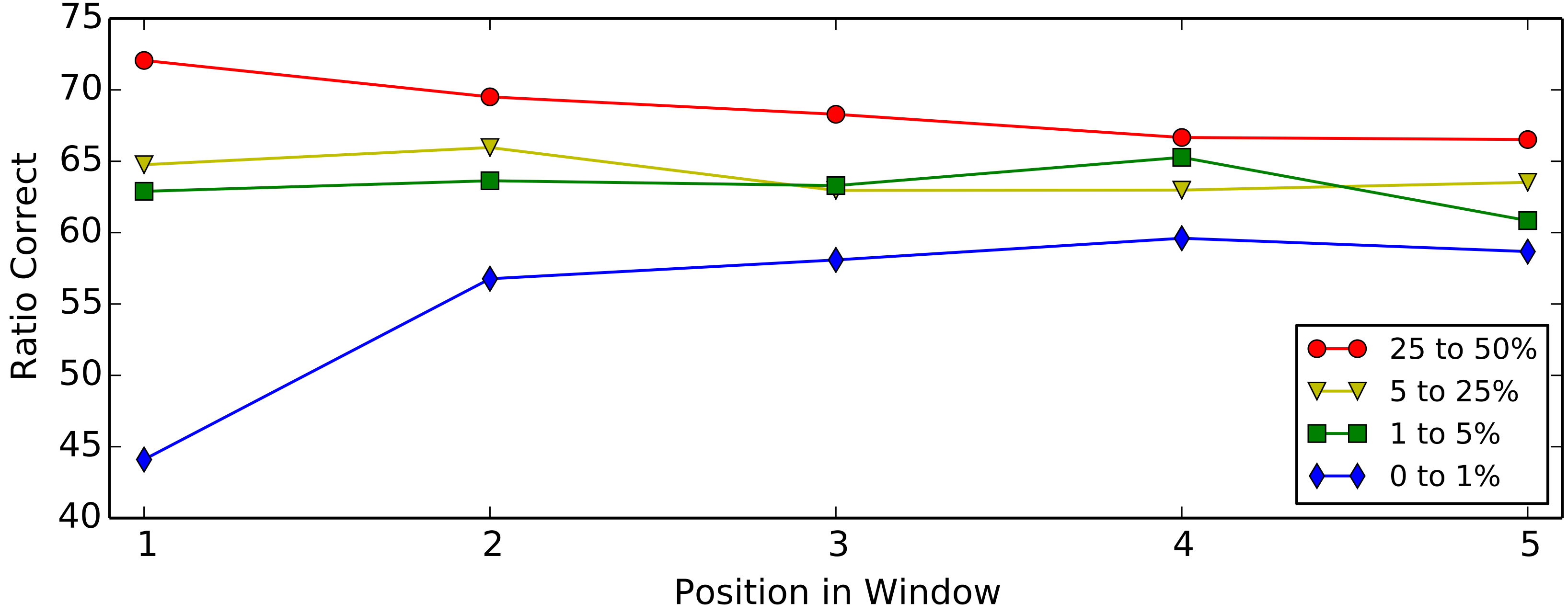
System	Configuration	BLEU	Word Prediction Accuracy	Letter Prediction Accuracy
Neural	no beam search	34.5	61.6%	86.8%
	beam size 12	36.2	63.6%	87.4%
Phrase-based	-	34.5	43.3%	72.8%

Recovery from Failure

- Ratio of words correct after first failure

System	Configuration	1	2	3	4	5
Neural	no beam search	55.9%	61.8%	61.3%	62.2%	61.1%
	beam size 12	58.0%	62.9%	62.8%	64.0%	61.5%
Phrase-based	-	28.6%	45.5%	46.9%	47.4%	48.4%

- Depending on probability of user word (neural, no beam)



Patching Translations

- Decoding speeds
  - translation speed with CPU: 100 ms/word
  - translation speed with GPU: 7ms/word
- To stay within 100ms speed limit
  - predict only a few words ahead (say, 5, in 5×7ms=35ms)
  - patch new partial prediction with old full sentence prediction
  - uses KL divergence to find best patch point in ± 2 word window
- May compute new full sentence prediction in background, return as update
- Only doing quick response reduces word prediction accuracy 61.6%$\rightarrow$56.4%

Overview

- Interactivity
- **Choices**
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Choices

- Trigger the passive vocabulary
- Display multiple translations for words and phrases

er	hat	seit	Monaten	geplant	,	im	März	einen	Vortrag	...
he has		**for months**		**the plan**		**in March**		**a lecture**		...
it has		**for months now**		**planned**	,	in	March	**a presentation**		...
he was		for several months		planned to		in the March		a speech		...
he has made		since	months	the pipeline		in March of		a statement		...
he did		for many months		scheduled		the March		a general		...

- Rank and color-highlight by probability of each translation
- Prefer diversity

Alternative Translations

Input Sentence

Er hat seit Monaten geplant, im November einen Vortrag in Baltimore zu halten.

Professional Translator

He planned for months to **give a lecture** in Baltimore in November.

give a presentation
present his work
give a speech
speak

User requests alternative translations for parts of sentence.

Bilingual Concordancer

entre autres(560/1554)

...d and made recommendations , " **inter alia** " , with respect to the follow...	...� des recommandations concernant , **entre autres** , les questions spécifiques suiva...
...on (EC) No 1995 / 2000 imposing , **inter alia** , a definitive anti @-@ dumping dut...	...995 / 2000 du Conseil instituant , **entre autres** , un droit antidumping définitif ...
...ervices . this increase , arising , **inter alia** , as a result of economic growth , ...	...nsports . cette augmentation , due **entre autres** facteurs à la croissance économi...
...of paragraph 1 the Commission may , **inter alia** , bring forward :	...aragraphe 1 , la Commission peut , **entre autres** , présenter :
... of stocks of obsolete pesticides , **inter alia** , by supporting projects aimed at s...	...r les stocks de vieux pesticides , **entre autres** en soutenant des projets à cet ef...
...wn rules of procedure which shall , **inter alia** , contain provisions for convening ...	...lement intérieur , qui contient , **entre autres** dispositions , les modalités de c...
...uch specific agreements may cover , **inter alia** , financing provisions , assignment...	...ords spécifiques peuvent porter , **entre autres** , sur les mécanismes financiers s...
...he internal market and concerning , **inter alia** , health and environmental protecti...	...hé intérieur et qui concernent , **entre autres** , la santé et la protection de l&...
...e product concerned) originating , **inter alia** , in Belarus and Russia (the count...	...it concerné ") originaire , **entre autres** , du Belarus et de Russie (ci @-@ ...
...e product concerned) originating , **inter alia** , in India .	...t concerné ") originaires , **entre autres** , de l ' Inde .

notamment(447/1554)

... the EU budget by addressing " **inter alia** " the problems of accountabili...	...get de l' Union , ce qui passe **notamment** par la résolution du problème de r...
...ates , the Commission has adopted , **inter alia** , Decision 2003 / 526 / EC (3) wh...	...es États membres , la Commission a **notamment** arrêté la décision 2003 / 526 / C...
...d equitable development involving , **inter alia** , access to productive resources , ...	... durable et équitable , impliquant **notamment** l' accès aux ressources produc...
...ertain products which could be used **inter alia** , as equipment on board ships but w...	...usceptibles d' être utilisés **notamment** comme équipements mis à bord , mai...
...nexes , taking into consideration , **inter alia** , available scientific , technical ...	...ion et à ses annexes , compte tenu **notamment** des informations scientifiques , tec...
...w that it is absolutely necessary , **inter alia** , because of enlargement , to find ...	...os; il est absolument nécessaire , **notamment** en raison de l' élargissement ...
...paragraphs 1 and 2 as appropriate , **inter alia** , by conducting studies and compili...	...ragraphes 1 et 2 le cas échéant , **notamment** en menant des études et en compilan...
...liability and efficiency , caused , **inter alia** , by insufficient technical and adm...	... et d' efficacité en raison , **notamment** , d' une interopérabilité tec...
...in the Programme shall be pursued , **inter alia** , by the following means :	...nis dans le programme , il convient **notamment** de mettre en oeuvre les moyens ci @-...

Overview

- Interactivity
- Choices
- **User Studies**
- Confidence
- Adaptation

Logging functions

- Different types of events are saved in the logging.
  - configuration and statistics
  - start and stop session
  - segment opened and closed
  - text, key strokes, and mouse events
  - scroll and resize
  - search and replace
  - suggestions loaded and suggestion chosen
  - interactive translation prediction
  - gaze and fixation from eye tracker

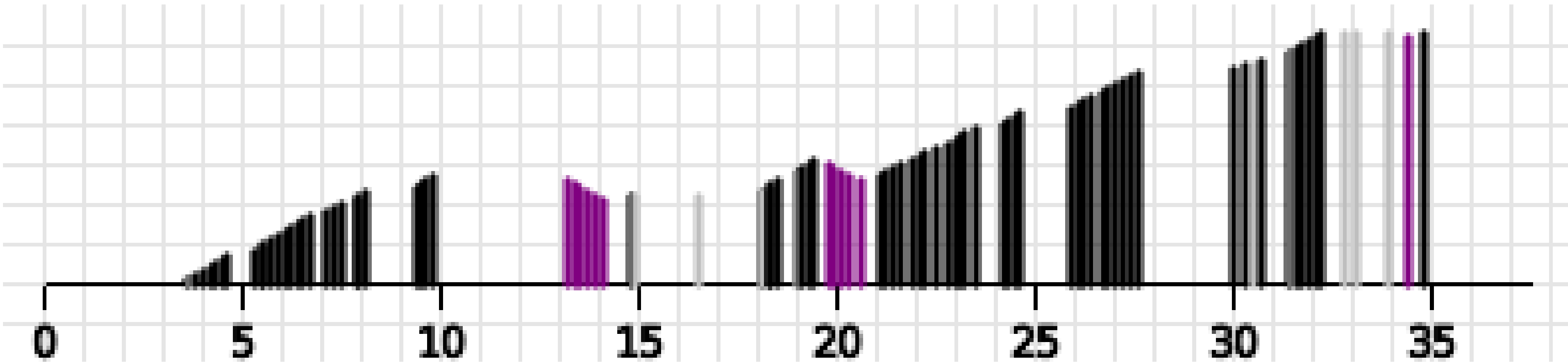
Logging functions

- In every event we save:
  - Type
  - In which element was produced
  - Time
- Special attributes are kept for some types of events
  - Diff of a text change
  - Current cursor position
  - Character looked at
  - Clicked UI element
  - Selected text

⇒ Full replay of user session is possible

Keystroke Log

Input: Au premier semestre, l'avionneur a livré 97 avions.
Output: The manufacturer has delivered 97 planes during the first half.



(37.5 sec, 3.4 sec/word)

black: keystroke, purple: deletion, grey: cursor move
height: length of sentence

Example of Quality Judgments

Src.	Sans se démonter, il s'est montré concis et précis.
MT	Without dismantle, it has been concise and accurate.
1/3	Without fail, he has been concise and accurate. *(Prediction+Options, L2a)*
4/0	Without getting flustered, he showed himself to be concise and precise. *(Unassisted, L2b)*
4/0	Without falling apart, he has shown himself to be concise and accurate. *(Postedit, L2c)*
1/3	Unswayable, he has shown himself to be concise and to the point. *(Options, L2d)*
0/4	Without showing off, he showed himself to be concise and precise. *(Prediction, L2e)*
1/3	Without dismantling himself, he presented himself consistent and precise. *(Prediction+Options, L1a)*
2/2	He showed himself concise and precise. *(Unassisted, L1b)*
3/1	Nothing daunted, he has been concise and accurate. *(Postedit, L1c)*
3/1	Without losing face, he remained focused and specific. *(Options, L1d)*
3/1	Without becoming flustered, he showed himself concise and precise. *(Prediction, L1e)*

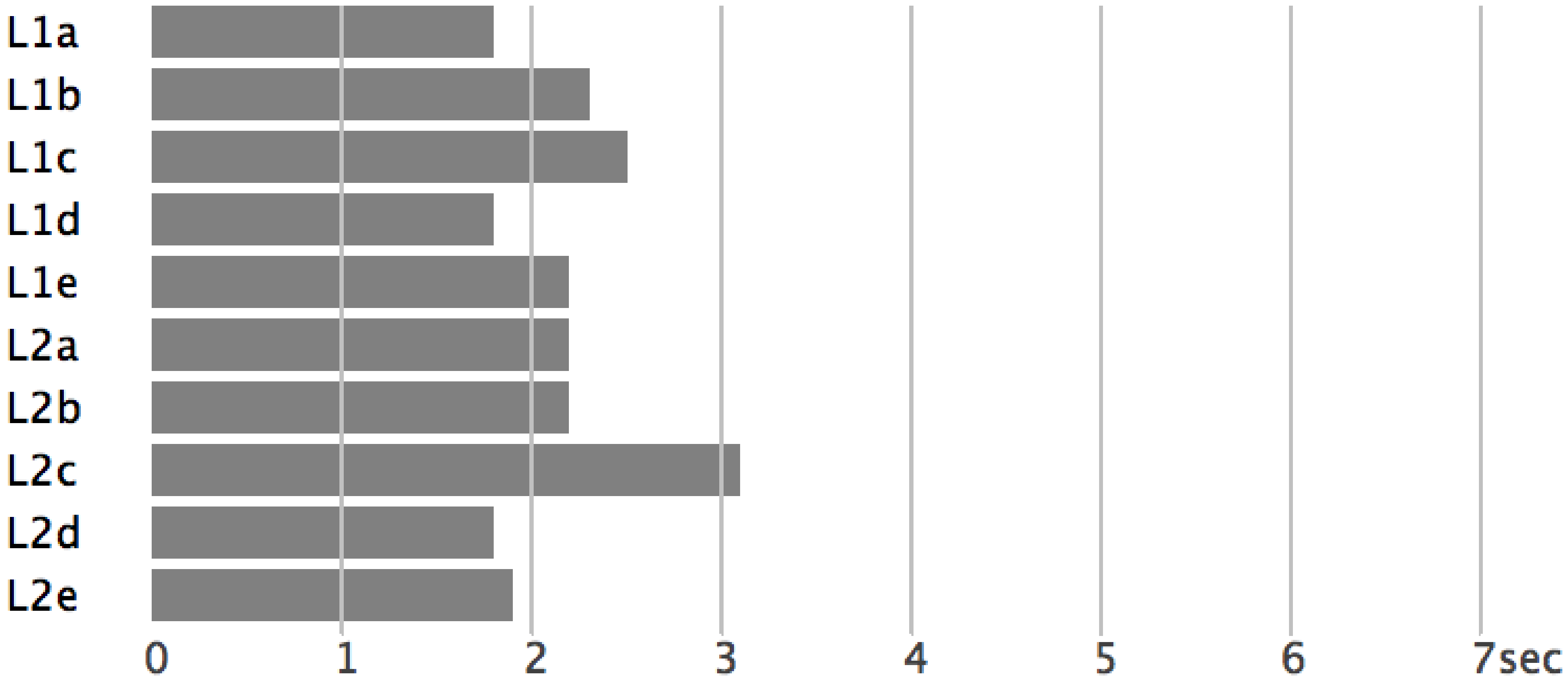
Main Measure: Productivity

Assistance	Speed	Quality
Unassisted	4.4s/word	47% correct
Postedit	2.7s (-1.7s)	55% (+8%)
Options	3.7s (-0.7s)	51% (+4%)
Prediction	3.2s (-1.2s)	54% (+7%)
Prediction+Options	3.3s (-1.1s)	53% (+6%)

Faster and Better, Mostly

User	Unassisted	Postedit		Options		Prediction		Prediction+Options	
L1a	3.3sec/word 23% correct	**1.2s** **39%**	**-2.2s** **+16%)**	**2.3s** **45%**	**-1.0s** **+22%**	**1.1s** **30%**	**-2.2s** **+7%)**	**2.4s** **44%**	**-0.9s** **+21%**
L1b	7.7sec/word 35% correct	**4.5s** **48%**	**-3.2s)** **+13%**	**4.5s** **55%**	**-3.3s** **+20%**	**2.7s** **61%**	**-5.1s** **+26%**	**4.8s** **41%**	**-3.0s** **+6%**
L1c	3.9sec/word 50% correct	**1.9s** **61%**	**-2.0s** **+11%**	**3.8s** **54%**	**-0.1s** **+4%**	**3.1s** **64%**	**-0.8s** **+14%**	**2.5s** **61%**	**-1.4s** **+11%**
L1d	2.8sec/word 38% correct	**2.0s** **46%**	**-0.7s** **+8%**	2.9s 59%	(+0.1s) (+21%)	2.4s 37%	(-0.4s) (-1%)	**1.8s** **45%**	**-1.0s** **+7%**
L1e	5.2sec/word 58% correct	**3.9s** **64%**	**-1.3s** **+6%**	4.9s 56%	(-0.2s) (-2%)	**3.5s** **62%**	**-1.7s** **+4%**	4.6s 56%	(-0.5s) (-2%)
L2a	5.7sec/word 16% correct	**1.8s** **50%**	**-3.9s** **+34%**	**2.5s** **34%**	**-3.2s** **+18%**	**2.7s** **40%**	**-3.0s** **+24%**	**2.8s** **50%**	**-2.9s** **+34%**
L2b	3.2sec/word 64% correct	2.8s 56%	(-0.4s) (-8%)	*3.5s* *60%*	*+0.3s* *-4%*	*6.0s* *61%*	*+2.8s* *-3%*	*4.6s* *57%*	*+1.4s* *-7%*
L2c	5.8sec/word 52% correct	**2.9s** **53%**	**-3.0s** **+1%**	4.6s 37%	(-1.2s) (-15%)	**4.1s** **59%**	**-1.7s** **+7%**	**2.7s** **53%**	**-3.1s** **+1%**
L2d	3.4sec/word 49% correct	3.1s 49%	(-0.3s) (+0%)	4.3s 51%	(+0.9s) (+2%)	3.8s 53%	(+0.4s) (+4%)	3.7s 58%	(+0.3s) (+9%)
L2e	2.8sec/word 68% correct	**2.6s** **79%**	**-0.2s** **+11%**	*3.5s* *59%*	*+0.7s* *-9%*	2.8s 64%	(-0.0s) (-4%)	*3.0s* *66%*	*+0.2s* *-2%*
avg.	4.4sec/word 47% correct	**2.7s** **55%**	**-1.7s** **+8%**	**3.7s** **51%**	**-0.7s** **+4%**	**3.2s** **54%**	**-1.2s** **+7%**	**3.3s** **53%**	**-1.1s** **+6%**

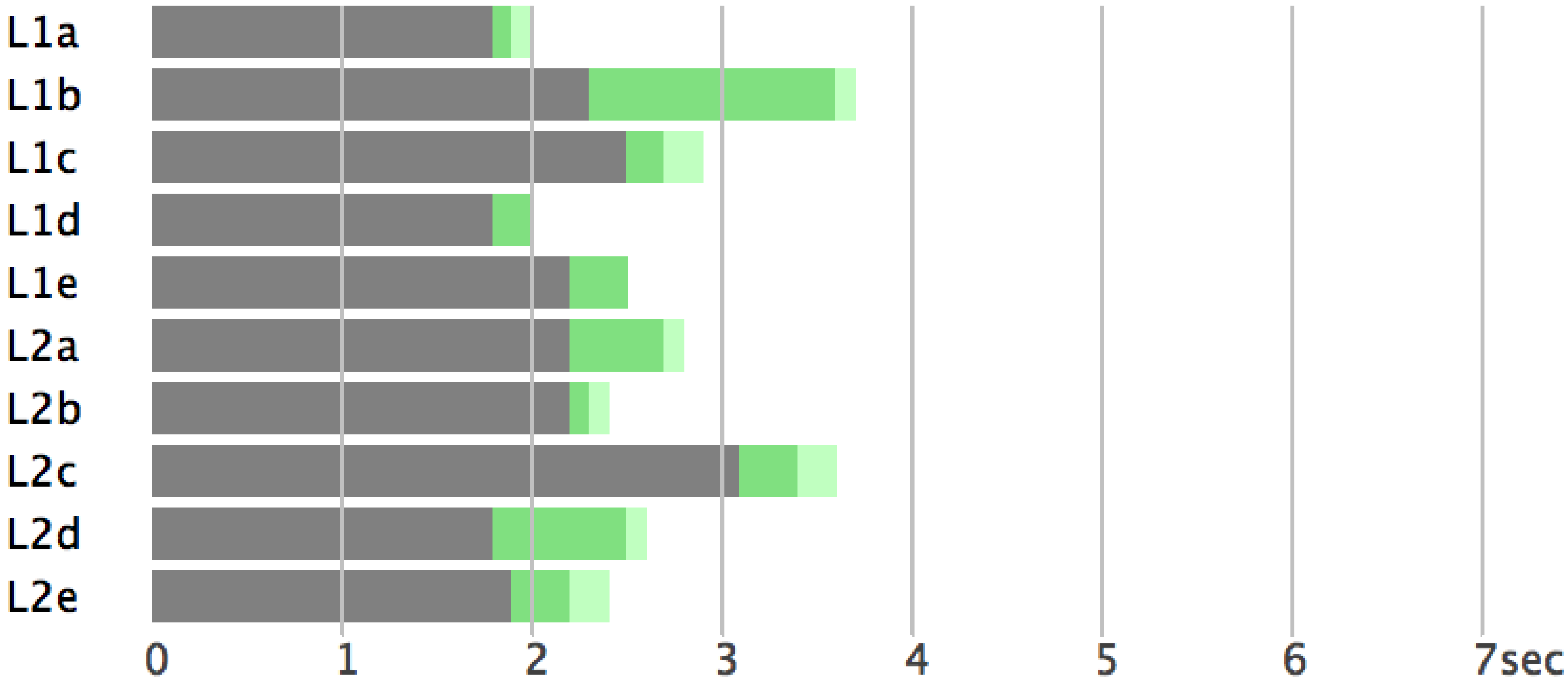
Unassisted Novice Translators



L1 = native French, L2 = native English, average time per input word

only typing

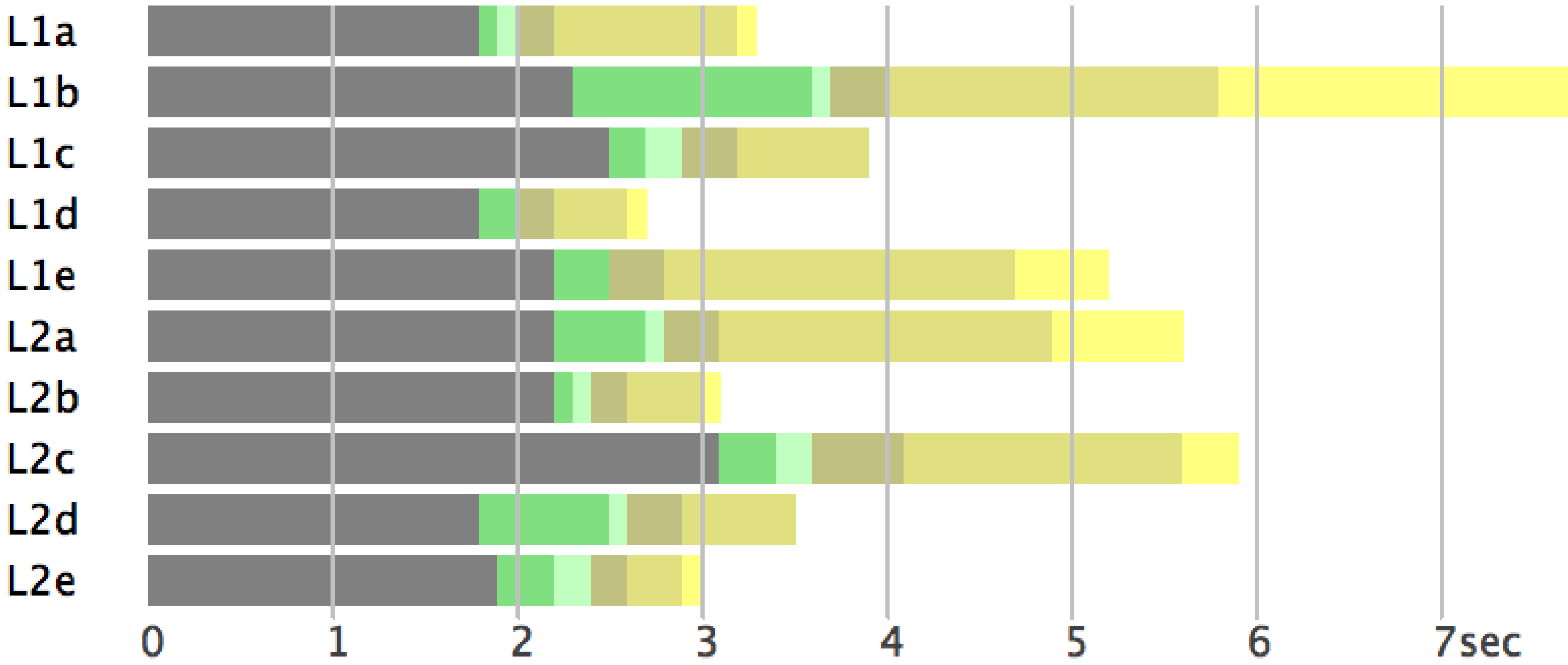
Unassisted Novice Translators



L1 = native French, L2 = native English, average time per input word

typing, initial and final pauses

Unassisted Novice Translators



L1 = native French, L2 = native English, average time per input word

typing, initial and final pauses, short, medium, and long pauses

most time difference on intermediate pauses

Activities: Native French User L1b

User: L1b	total	init-p	end-p	short-p	mid-p	big-p	key	click	tab
Unassisted	7.7s	1.3s	0.1s	0.3s	1.8s	1.9s	2.3s	-	-
Postedit	4.5s	1.5s	0.4s	0.1s	1.0s	0.4s	1.1s	-	-
Options	4.5s	0.6s	0.1s	0.4s	0.9s	0.7s	1.5s	0.4s	-
Prediction	2.7s	0.3s	0.3s	0.2s	0.7s	0.1s	0.6s	-	0.4s
Prediction+Options	4.8s	0.6s	0.4s	0.4s	1.3s	0.5s	0.9s	0.5s	0.2s

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Options	4.5s	0.6s	0.1s	0.4s	0.9s	0.7s	1.5s	0.4s	-
Prediction	2.7s	0.3s	0.3s	0.2s	0.7s	0.1s	0.6s	-	0.4s
Prediction+Options	4.8s	0.6s	0.4s	0.4s	1.3s	0.5s	0.9s	0.5s	0.2s

Slightly less time spent on typing

Activities: Native French User L1b

User: L1b	total	init-p	end-p	short-p	mid-p	big-p	key	click	tab
Unassisted	7.7s	1.3s	0.1s	0.3s	1.8s	1.9s	2.3s	-	-
Postedit	4.5s	1.5s	0.4s	0.1s	1.0s	0.4s	1.1s	-	-
Options	4.5s	0.6s	0.1s	0.4s	0.9s	0.7s	1.5s	0.4s	-
Prediction	2.7s	0.3s	0.3s	0.2s	0.7s	0.1s	0.6s	-	0.4s
Prediction+Options	4.8s	0.6s	0.4s	0.4s	1.3s	0.5s	0.9s	0.5s	0.2s

Less pausing

Slightly less time spent on typing

Activities: Native French User L1b

User: L1b	total	init-p	end-p	short-p	mid-p	big-p	key	click	tab
Unassisted	7.7s	1.3s	0.1s	0.3s	1.8s	1.9s	2.3s	-	-
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Prediction	2.7s	0.3s	0.3s	0.2s	0.7s	0.1s	0.6s	-	0.4s
Prediction+Options	4.8s	0.6s	0.4s	0.4s	1.3s	0.5s	0.9s	0.5s	0.2s

Less pausing

Especially less time in big pauses

Slightly less time spent on typing

Overview

- Interactivity
- Choices
- User Studies
- **Confidence**
- Adaptation

Confidence

- Machine translation engine indicates where it is likely wrong (also known as quality estimation — Lucia Specia)
- Different Levels of granularity
  - document-level (SDL's "TrustScore")
  - sentence-level
  - word-level
- What are we predicting?
  - how useful is the translation — on a scale of (say) 1–5
  - indication if post-editing is worthwhile
  - estimation of post-editing effort
  - pin-pointing errors

Sentence-Level Confidence

- Translators are used to "Fuzzy Match Score"
  - used in translation memory systems
  - roughly: ratio of words that are the same between input and TM source
  - if less than 70%, then not useful for post-editing
- We would like to have a similar score for machine translation
- Even better
  - estimation of post-editing time
  - estimation of from-scratch translation time
  - → can also be used for pricing
- Active research question, see also shared task at WMT 2013

Word-Level Confidence

Input Sentence

Er hat seit Monaten geplant, im November einen Vortrag in Baltimore zu halten.

Machine Translation

He has for months planned in November give a lecture in Baltimore.

Word-Level Confidence

Input Sentence

Er hat seit Monaten geplant, im November einen Vortrag in Baltimore zu halten.

Machine Translation

He has for months planned in November give a lecture in Baltimore.

Note: different color for wrong words and reordered words
(inserted words? missing words?)

Automatic Reviewing

- Can we identify errors in human translations?
  - missing / added information
  - inconsistent use of terminology

Input Sentence

Er hat seit Monaten geplant, im November einen Vortrag in Baltimore zu halten.

Human Translation

Moreover, he planned for months to give a lecture in Baltimore.

Overview

- Interactivity
- Choices
- User Studies
- Confidence
- **Adaptation**

Adaptation

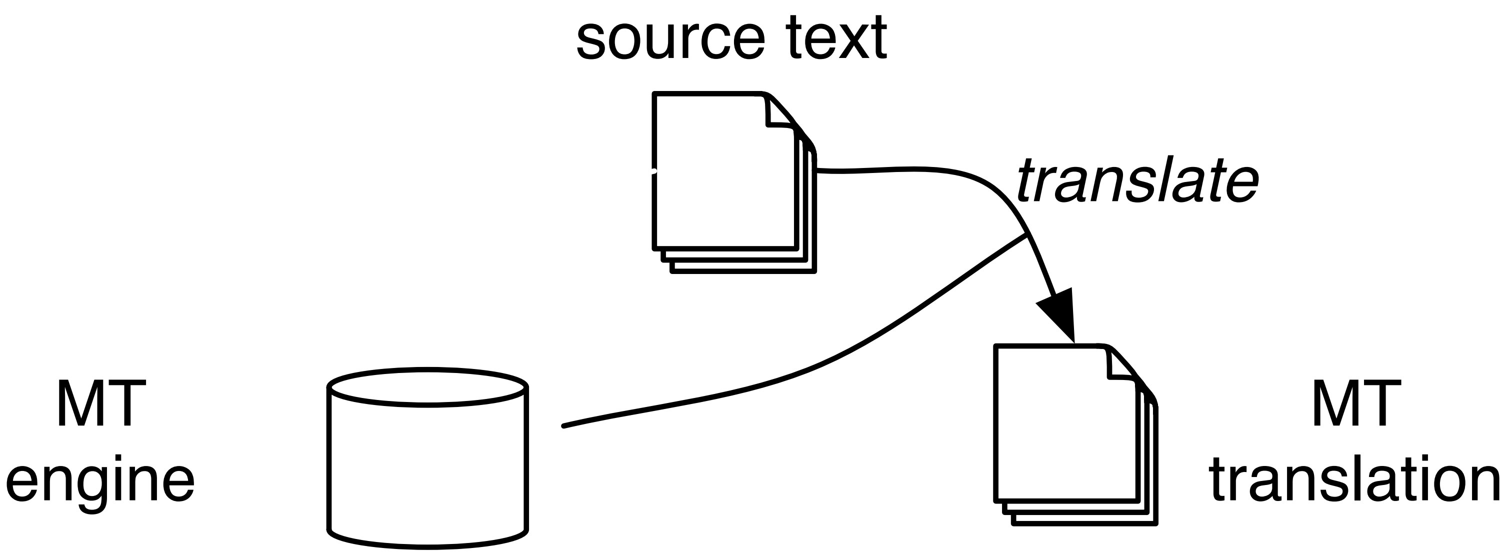
- Machine translation works best if optimized for domain

- Typically, large amounts of out-of-domain data available
  - European Parliament, United Nations
  - unspecified data crawled from the web

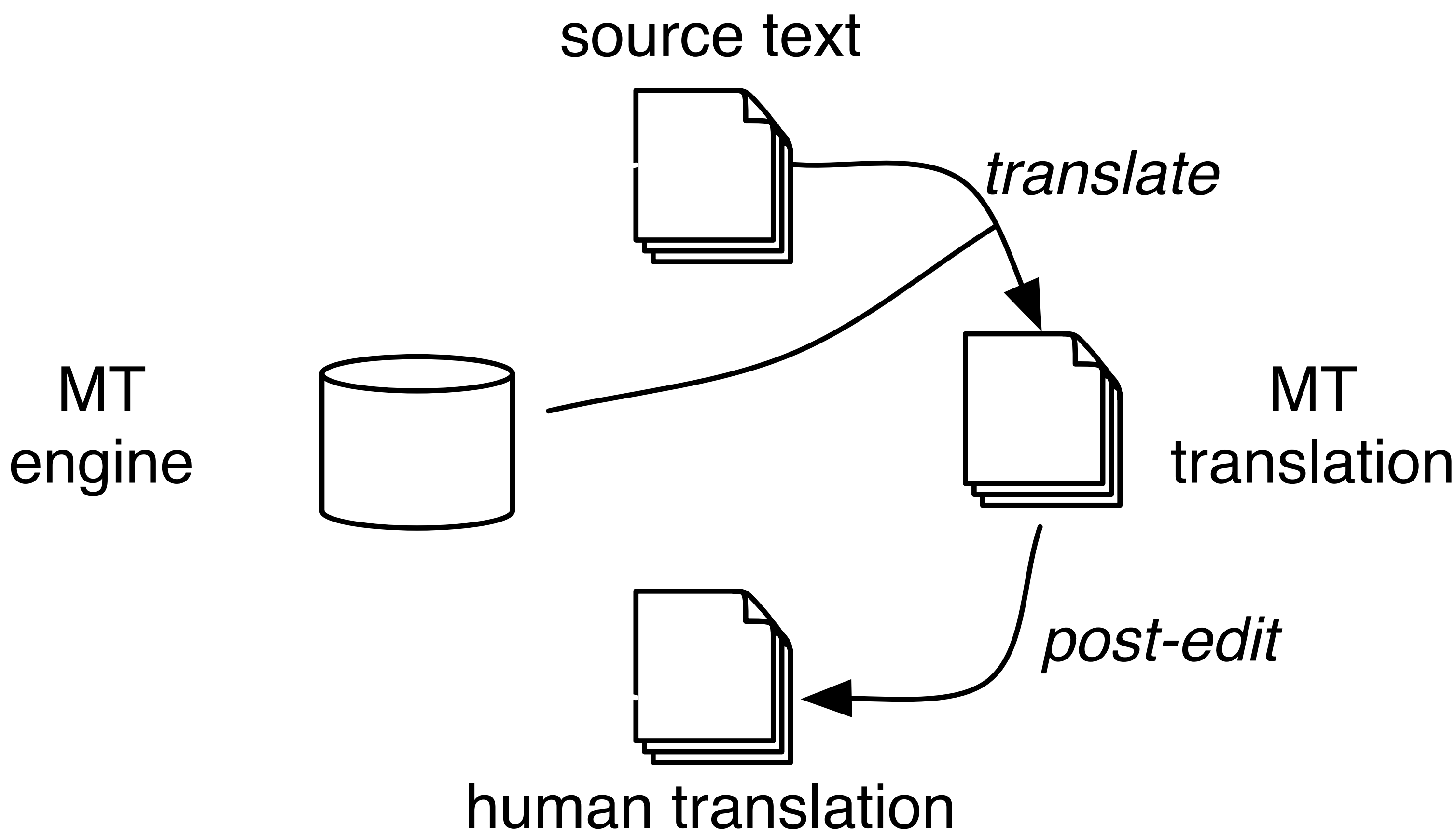
- Little in-domain data (maybe 1% of total)
  - information technology data
  - more specific: IBM's user manuals
  - even more specific: IBM's user manual for same product line from last year
  - and even more specific: sentence pairs from current project

- Various domain adaptation techniques researched and used

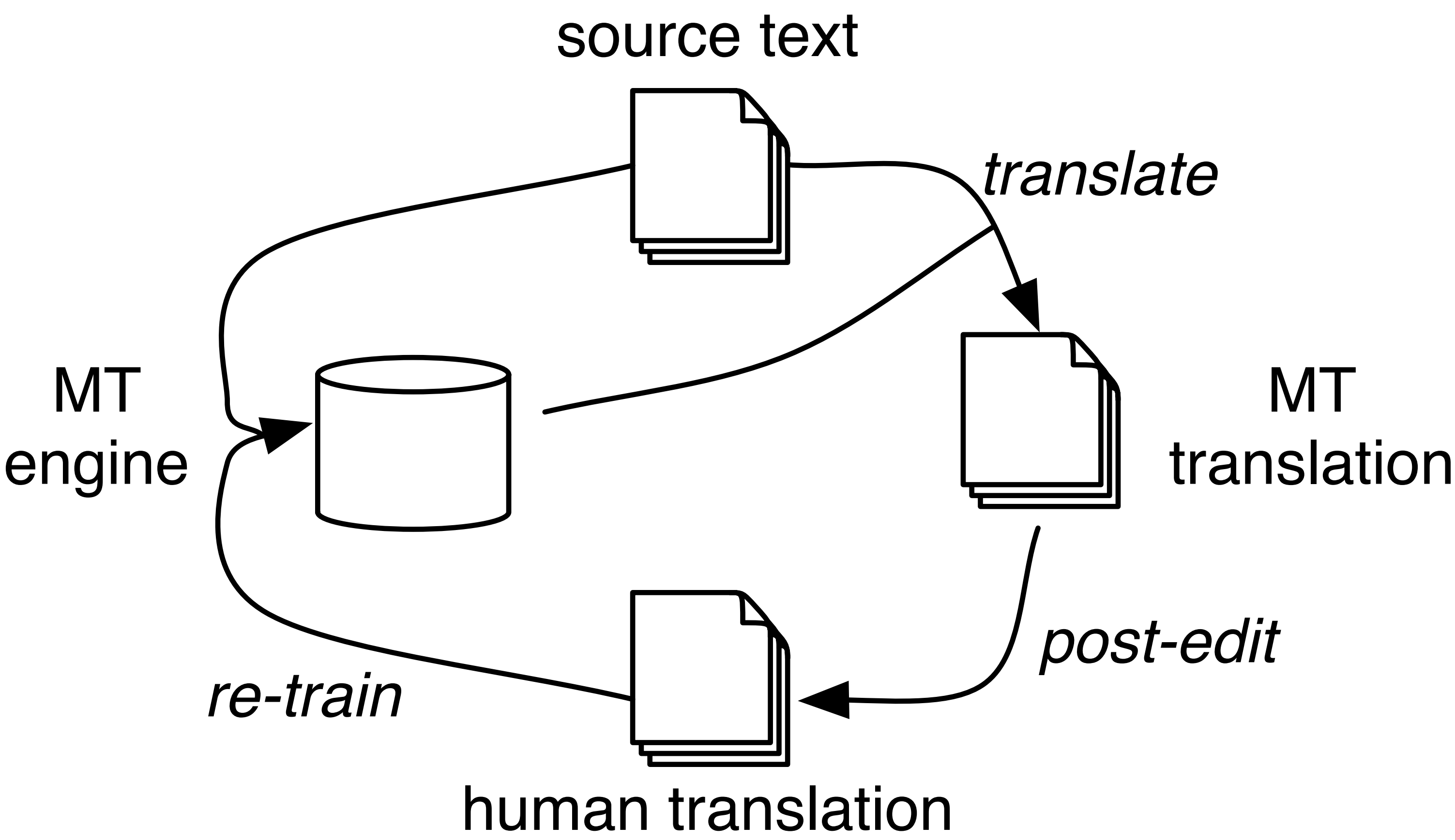
Incremental Updating



Incremental Updating



Incremental Updating



Incremental Updating

- Statistical machine translation
  - store corpus in memory
  - add new sentence pairs to corpus
  - indexed data structure (suffix arrays) allow quick look-up of translations
- Neural machine translation
  - fine tuning
  - special handling of new words
  - ongoing research in this area

Summary

- Use fo machine translation in translation industry becomes standard
- Interaction between machine and human open problem
- Not very much research in this area
- Open source toolkit: CASMACAT