Universitat Politècnica de València

Master in Artificial Intelligence, Pattern Recognition and Digital Imaging

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MACHINE TRANSLATION

4. Interactive Machine Translation

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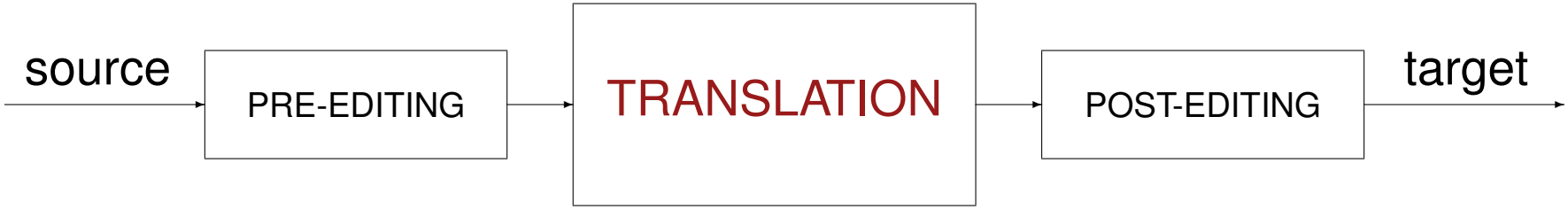
Machine translation (MT)

- Existing MT technologies are currently seen as promising approaches to help produce high-quality translations (HQT) cost-effectively.
- However, the current state of the art in machine translation is still very far from allowing fully automatic HQT for many tasks. For some other tasks, human parity and super-human performance has been achieved [Toral 2020].
- (Pre-) post-editing



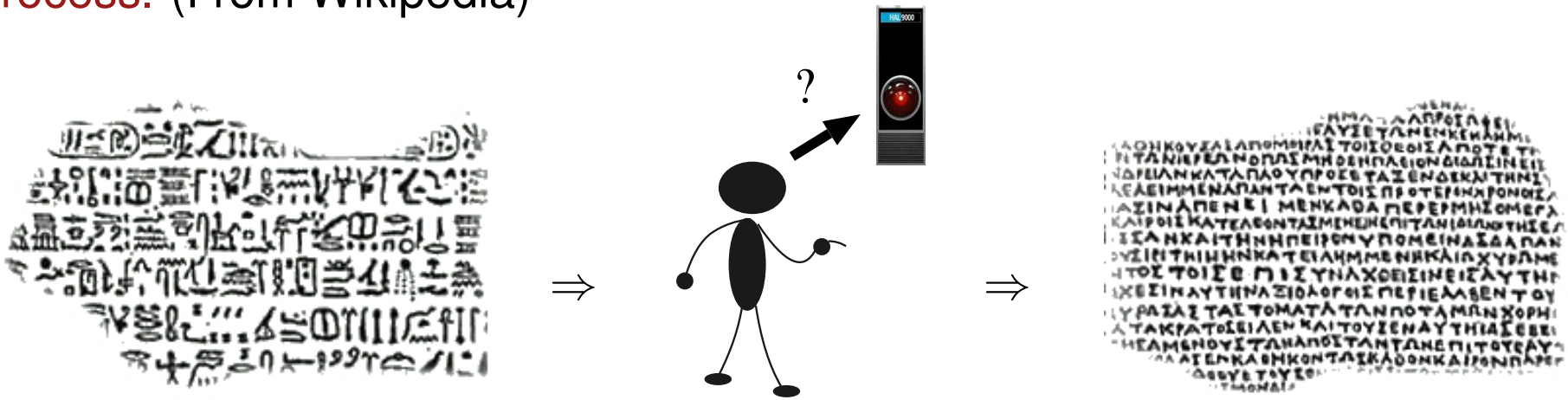
- Many problems could have been avoided by making the source text "simpler".

Machine translation (MT)

- Pre-editing:
  - Text format (automatic): tokenization, lowercase, place holders, categorization, ...
  - Help the automatic translator (automatic and/or manual): reordering, vocabulary changes, ...
- Post-editing:
  - Text format (automatic): des-tokenization, truecase, replace place holders, replace categories, ...
  - Correction and debuggig (automatic and/or manual): automatic post-editing to correct systematic errors, human post-editing,...

HQT: Computer-assisted translation (CAT)

- CAT is a form of translation wherein a human translator translates texts using computer software designed to support and facilitate the translation process. (From Wikipedia)



- Other names: computer-aided translation, computer–assisted translation, machine–aided translation, machine-assisted translation.
- Historically, CAT and MT have been considered as different but close technologies [Kay, MT 1997]
- Nowadays, MT is a tool in CAT (+human post-editing)

HQT: Human-machine interaction (HMI)

- In classical MT and CAT, the interaction between human translators and machines is very limited.
- At the origin: HMI focused on disambiguation of the source text or for updating user dictionaries or for searching through dictionaries [Slocum, CL 1985][Whitelock et al., COLING 1986].
- In the industry: simple HMI by post-editing the translations from:
  - Translation memories (TM)
  - Machine translation (MT) systems.
  - Queries (glossaries, synonyms, ...)
- Another idea: A complete MT system is used to produce target sentence hypotheses, which can be accepted or amended by a human translator. Each correct text segment is then used by the MT system as additional information to achieve further, hopefully improved suggestions. [Foster et al., MT 1997] [Barrachina et al., CL 2008][Casacuberta et al., CACM 2008].

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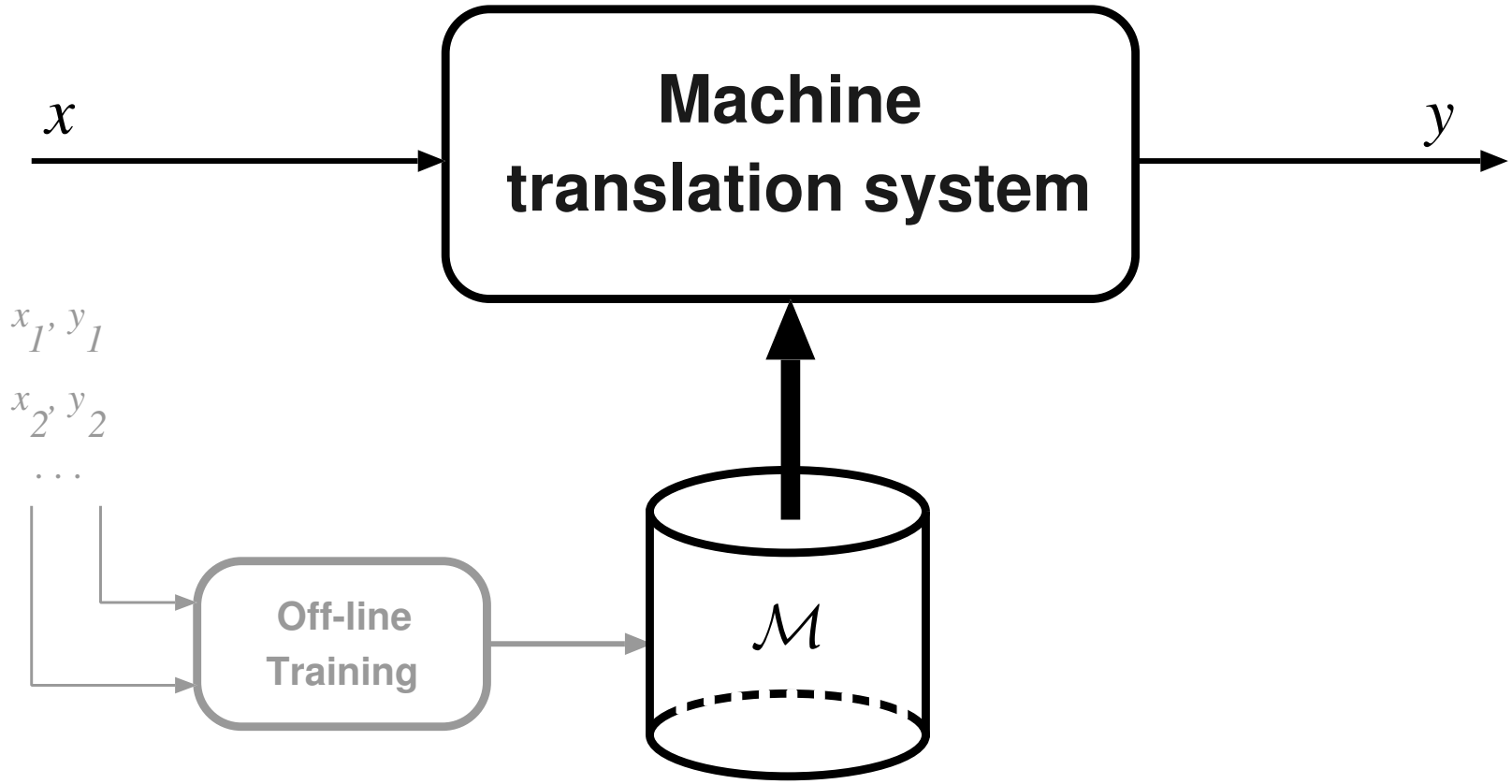
Diagram of a SMT/NMT system



Post-editing: example

Translating the source sentence *"Click OK to close the print dialog"* into Spanish (the reference is *"Haga clic en ACEPTAR para cerrar el cuadro de diálogo de impresión"*):

Post-editing: example

Translating the source sentence *"Click OK to close the print dialog"* into Spanish (the reference is *"Haga clic en ACEPTAR para cerrar el cuadro de diálogo de impresión"*):

System: Haga clic para cerrar el diálogo de impresión

Post-editing: example

Translating the source sentence *"Click OK to close the print dialog"* into Spanish (the reference is *"Haga clic en ACEPTAR para cerrar el cuadro de diálogo de impresión"*):

System: Haga clic para cerrar el diálogo de impresión

User: Haga clic **en** para cerrar el diálogo de impresión

Post-editing: example

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System: Haga clic para cerrar el diálogo de impresión

User: Haga clic **en** para cerrar el diálogo de impresión

User: Haga clic en **ACEPTAR** para cerrar el diálogo de impresión

Post-editing: example

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User: Haga clic en ACEPTAR para cerrar el cuadro **de** diálogo de impresión

User: Haga clic en ACEPTAR para cerrar el cuadro de diálogo de impresión

Result: Haga clic **en ACEPTAR** para cerrar el **cuadro de** diálogo de impresión

TOTAL: Four word-strokes

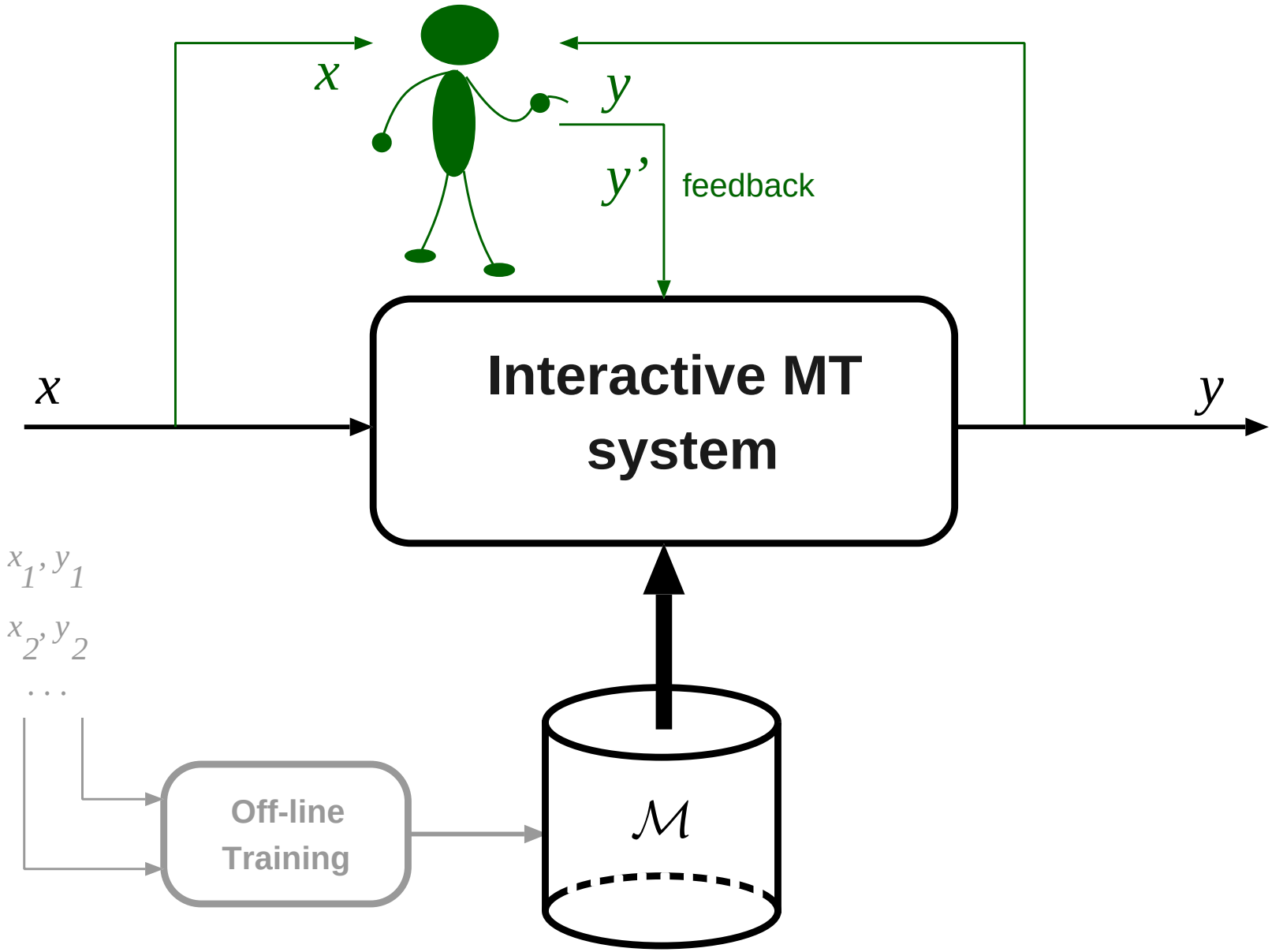
Introduction to interactive machine translation (IMT)

- IMT (or interactive CAT) aims to increase the overall (MT + human) productivity by incorporating human correction activities within the translation process itself

Main idea in IMT:

- Use a MT system to produce target text segments that can be accepted or amended by a human translator; these correct(ed) segments are then used by the MT system as additional information to achieve further, hopefully improved suggestions

Diagram of an interactive MT system



Human-machine (keyboard) interactive process: example

Translating the source sentence (x) *"Click OK to close the print dialog"* into Spanish:
(the reference is *"Haga clic en ACEPTAR para cerrar el cuadro de diálogo de impresión"*):

System ($\hat{y}_s$): Haga clic para cerrar el diálogo de impresión

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User (y_p): Haga clic **en**

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User (y_p): Haga clic en ACEPTAR para cerrar el **cuadro**

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User (y_p): Haga clic en ACEPTAR para cerrar el **cuadro**

System ($\hat{y}_s$): de diálogo de impresión

User (y_p): Haga clic en ACEPTAR para cerrar el cuadro de diálogo de impresión

Result ($\hat{y}$): Haga clic **en** ACEPTAR para cerrar el **cuadro** de diálogo de impresión

TOTAL: Two word-strokes

Interactive machine translation: the original idea

- These ideas were studied in the *TransType* (TT) project [Foster et al. EMNLP 2002] and have been throughly explored in the *TransType-2* (TT2) project [Barrachina et al. CL 2008], in the *MIPRCV* project [Toselli et al. 2011], in the *Caitra* system [Koehn ACL 2009], in the *CasMaCat* project [Alabau et al. PBML 2013] and in several Prometeo projects.

- In TT, the IMT system suggests the best target word that follows the given prefix, however in TT2, the IMT system suggests the best complete suffix. In MIPRCV simple features were added to IMT and in CasMaCat, new advanced features have been tested.

- Current approach: A no left-to-right interaction where the user can fix any word in the translation using PBSMT [Domingo et al. MTJ 2017)] or hierarchical SMT [González et al. CoNLL 2016] or neural machine translation [Peris et al. CSL 2017].

Prefix-based text prediction for interactive machine translation

- Given a source text x and a "correct" *prefix* y_p of the target text, search for a *suffix* $\hat{\mathsf{y}}_s$, that maximizes the posterior probability over all possible suffixes:

$$\hat{\mathsf{y}}_s = \underset{\mathsf{y}_s}{\operatorname{argmax}} \ \Pr(\mathsf{y}_s \mid \mathsf{x}, \mathsf{y}_p)$$

- Taking into account that $\Pr(\mathsf{y}_p|\mathsf{x})$ does not depend on y_s, we can re-write:

$$\begin{aligned} \hat{\mathsf{y}}_s &= \underset{\mathsf{y}_s}{\operatorname{argmax}} \ \frac{\Pr(\mathsf{y}_p\mathsf{y}_s|\mathsf{x})}{\Pr(\mathsf{y}_p|\mathsf{x})} \\ &= \underset{\mathsf{y}_s}{\operatorname{argmax}} \ \Pr(\mathsf{y}_p\mathsf{y}_s \mid \mathsf{x}) \end{aligned}$$

- $\Pr(\mathsf{y}_p\mathsf{y}_s \mid \mathsf{x})$: PBSMT or NMT
- Text-input MT is a particular case, where $\mathsf{y}_p = \lambda$
- Main difference of IMT vs. MT: search over the set of suffixes

Multiple segment-based text prediction for IMT
(Peris et al. CSL 2017)(Domingo et al. MTJ 2017)

- Given a source text x and a set of N "correct" *non-overlapping, validated segments*, including a one-word segment with the word the user has corrected $\mathsf{f}_1^N = \mathsf{f}_1 \ldots \mathsf{f}_N$, search for a new set of N *segments* $\hat{\mathsf{y}}_1 \ldots \mathsf{y}_N$, where each $\hat{\mathsf{y}}_i$ fills the space between two corrected segments f_i and f_{i+1}, such that: possible suffixes:

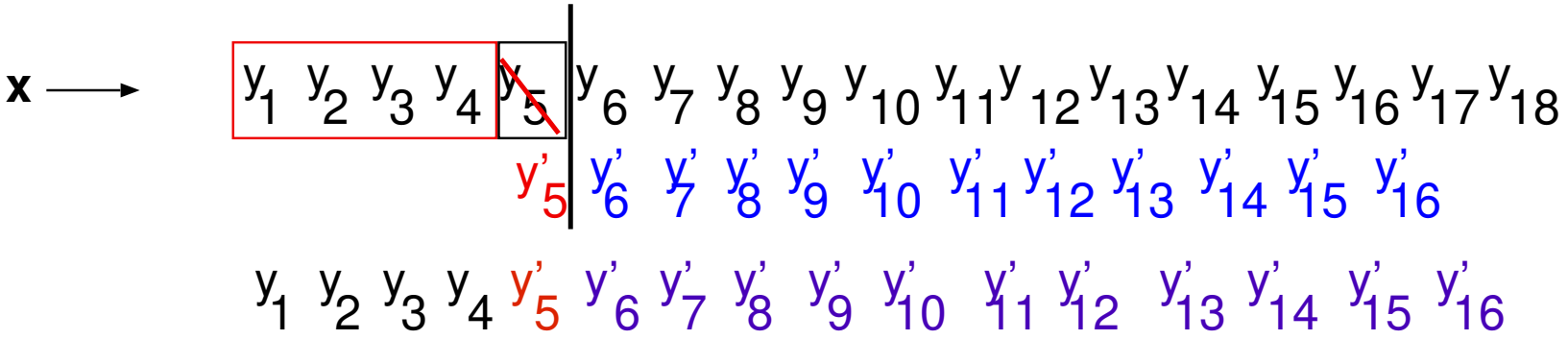
$$\hat{\mathsf{y}}_1 \ldots \hat{\mathsf{y}}_N = \underset{\mathsf{y}_1 \ldots \mathsf{y}_N}{\text{argmax}} \; \Pr(\mathsf{y}_1 \ldots \mathsf{y}_N \mid \mathsf{x}, \mathsf{f}_1 \ldots \mathsf{f}_N)$$

- With some simple assumptions, we can re-write:

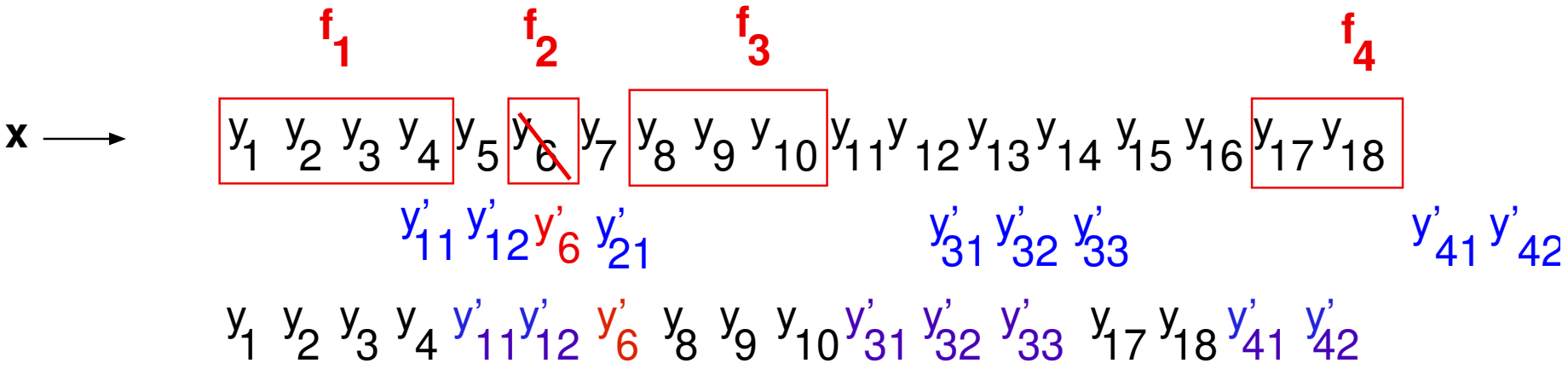
$$\hat{\mathsf{y}}_1 \ldots \hat{\mathsf{y}}_N = \underset{\mathsf{y}_1 \ldots \mathsf{y}_N}{\text{argmax}} \; \Pr(\mathsf{f}_1 \mathsf{y}_1 \ldots \mathsf{f}_N \mathsf{y}_N \mid \mathsf{x})$$

- $\Pr(\mathsf{f}_1 \mathsf{y}_1 \ldots \mathsf{f}_N \mathsf{y}_N \mid \mathsf{x})$: Log-linear models or encoder-decoder NMT
- Main difference of IMT vs. MT: search over the set of all possible substrings of the translations of x , constrained by the sequence of segments $\mathsf{f}_1 \ldots \mathsf{f}_N$.
- With a XML markup scheme in PB-based decoders or with a forced decoding in NMT.

Prefix vs. segment based prediction



Prefix-based IMT



Segment-based IMT

Evaluating MT and IMT systems

FOUR MEASURES

- TRANSLATION ERROR RATE (TER):
  The number of edits required to change a system output into one of the references. A previous score was TRANSLATION WORD ERROR RATE (TWER) that computes the minimum number of *word* insertions, deletions and substitutions needed to edit the system output into a reference.
- WORD-STROKE RATIO (WSR):
  Number of user interactions that are necessary to achieve the reference target divided by the number of running words. In each interaction only one wrong word is changed.
- TRANSLATION CHARACTER ERROR RATE (CER)
- KEY-STROKE RATIO (KSR)
- MOUSE ACTION RATIO (MAR):
  Number of mouse actions made by the user, divided by the total number of words in the final hypothesis.

Summary of prefix-based IMT experimental results in TT2

[Barrachina et al. CL 2008]

- Benchmark corpora: Xerox printer manuals (XRCE2) (Train: 50K bisentences and test 1K sentences) and EU bulletin (EU) (Train: 200K bisentences and test 800 sentences). English-Spanish, English-German and English-French.

- Results (WSR[↓], TWER[↓]) :

DATA: XRCE2	SFST (1-best)	
	WSR	TWER
English-Spanish	27.4	43.1
Spanish-English	31.7	51.4
English-French	65.1	73.8
French-English	58.5	71.9
English-German	55.4	81.3
German-English	55.0	78.5

DATA: EU	SFST (1-best)	
	WSR	TWER
English-Spanish	52.1	55.8
Spanish-English	48.5	52.5
English-French	62.2	53.9
French-English	60.5	49.2
English-German	49.6	65.5
German-English	44.0	66.6

Similar results were achieved with phrase-based models

Human evaluation in TT2 project

[Casacuberta et al. CACM 2008]

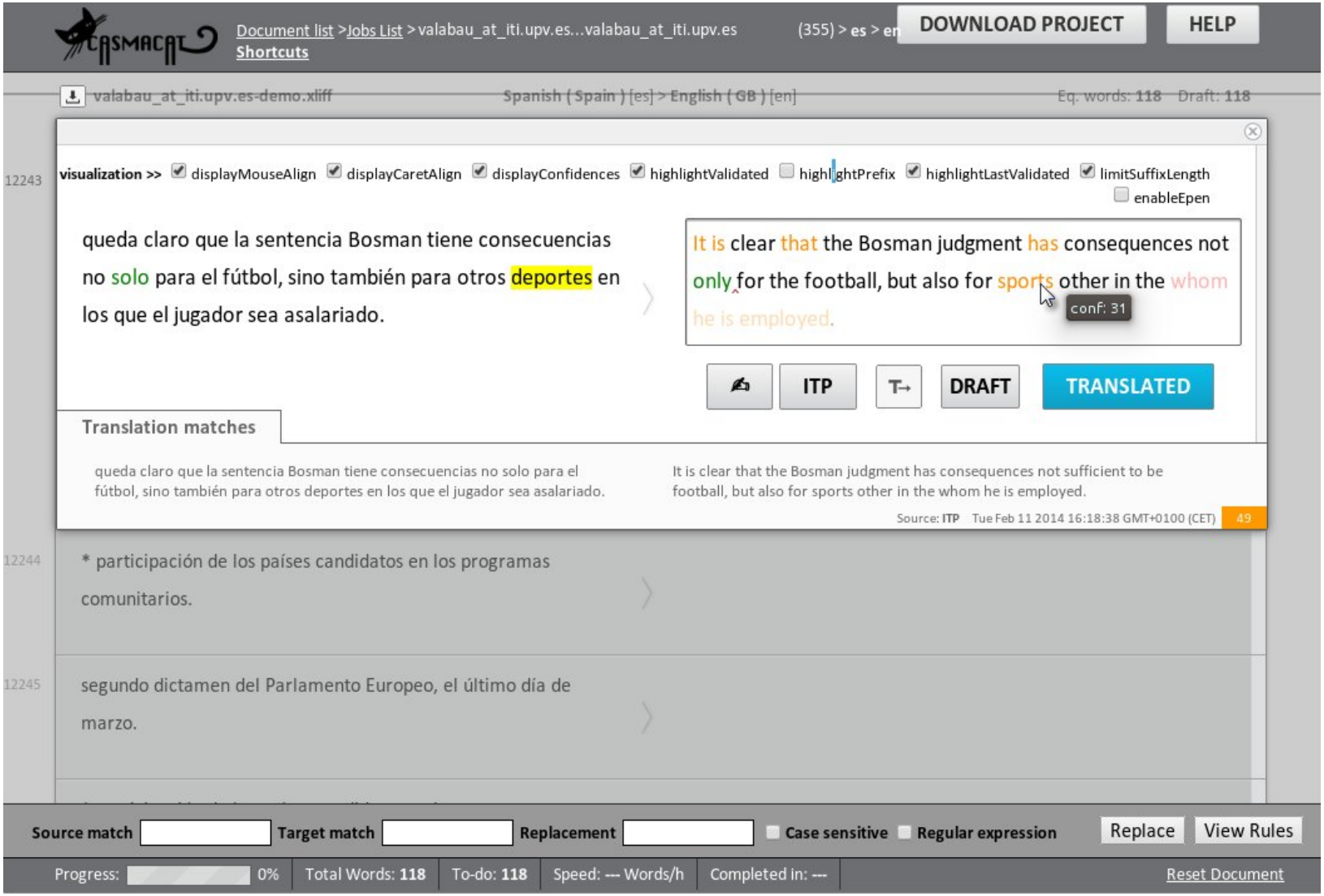
- Assessment: to measure the overall time required to translate a test corpus using the IMT system and without any system.
- Six professional translators, recruited from the two translation agencies. Five rounds during 18 months using Xerox corpus.
- Human evaluation: Overall, an IMT system can allow translators to increase their productivity while maintaining high-quality (about a save of 10-15% of human effort) depending on the task.

Human evaluation in MIPRCV

[Alabau et al. EAMT 2012]

- First field trial
  - 10 users aged 26-43.
  - 60 sentences from English-Spanish EU corpus.
  - Results:
    - the time spent per sentence in the IMT system was higher than in PE.
    - the effectiveness was slightly higher for IMT (higher final BLEU)
    - IMT failed to succeed in questions regarding the system being easy to use, consistent, and reliable.
- Second field trial
  - 15 users aged 23-24.
  - 60 sentences from English-Spanish EU corpus.
  - Results:
    - IMT was more efficient than with PE (less iterations)
    - IMT was perceived as more helpful.

CasMaCat interface



Human evaluation in CasMaCat project

- First field trial (2012).
  - Post-editing vs. from scratch,
  - Six freelance translators. $\approx$ 12000 words from new stories (en-es) collected from CNN, Fox News, NY Times
  - Results: PE produces a substantial time saving.
- Second field trial (2013). [Sanchis et al. MTJ 2014]
  - Post-editing, IMT and advanced IMT.
  - Nine freelance translators and four reviewers. $\approx$ 10000 words in 460 segments from WMT-2012 NC corpus
  - Results: IMT minimizes the number of key strokes with a little bit higher translation time. The productivity with advanced IMT decreased but the human translators liked the advanced features (IMT requires some human training)
- Third field trial (2014).
  - IMT vs PE. IMT + On-line learning and active learning. Use of the e-pen.
  - 7 post-editors. $\approx$ 4500 words. Additional trials.
  - Results: IMT becomes more productive than PE over time. Active learning achieves better quality/effort ratio, OL is faster if time outside workbench is not accounted. E-pen requires specific UI in tablet

More info in http://casmacat.eu/

Summary of segment-based IMT experimental results

[Peris et al. CSL 2017]

- Benchmark corpora: Xerox printer manuals (XRCE2) (Train: 50K bisentences and test 1K sentences) and EU bulletin (EU) (Train: 200K bisentences and test 800 sentences). English-Spanish. Segment-based prediction. NMT was used.

- Results(WSR[↓], TER[↓], MAR[↓]):

DATA:	SMT Prefix-based			NMT Prefix-based			NMT Segment-based	
XRCE2	TER	WSR	MAR	TER	WSR	MAR	WSR	MAR
English-Spanish	29.1	31.1	9.6	29.2	20.9	7.9	19.4	13.2
Spanish-English	32.5	29.7	10.6	30.0	24.0	9.8	21.8	11.9

DATA:	SMT Prefix-based			NMT Prefix-based			NMT Segment-based	
EU	TER	WSR	MAR	TER	WSR	MAR	WSR	MAR
English-Spanish	43.3	45.7	10.3	46.2	34.6	7.9	30.3	12.7
Spanish-English	41.3	45.6	10.5	45.2	35.1	8.2	30.5	13.7

More INMT experimental results with Transformer

[Peris 2019]

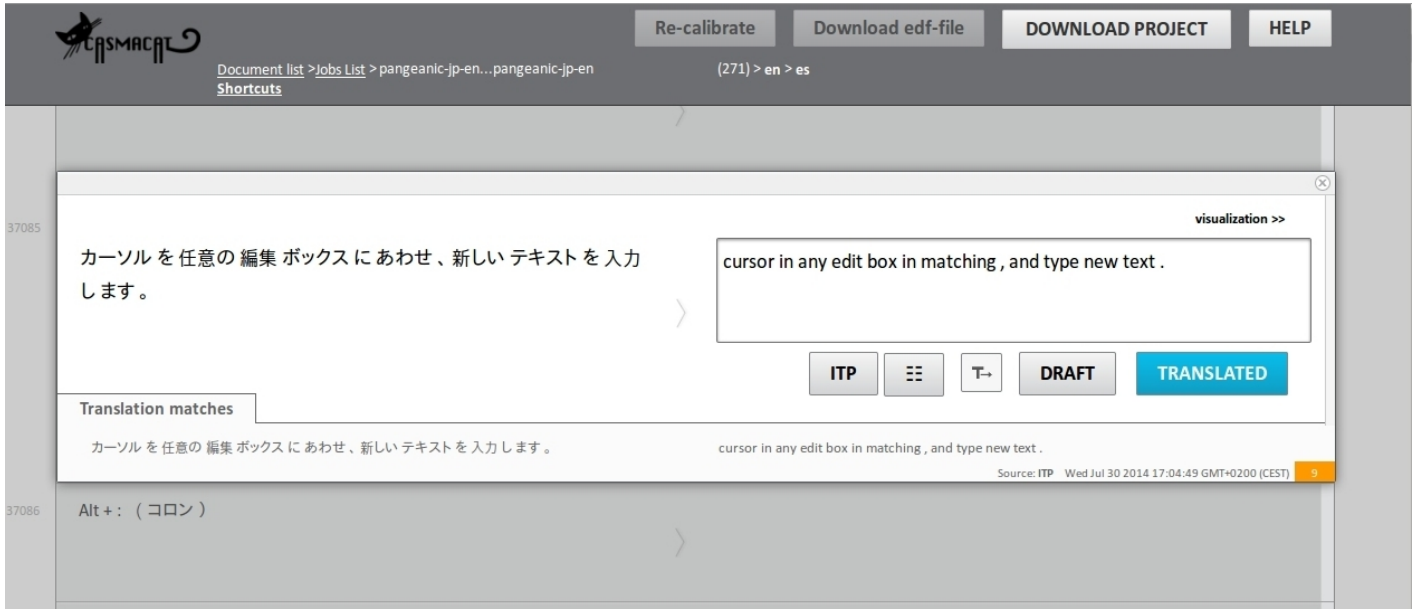
- Benchmark corpora: Xerox printer manuals (XRCE2), UFAL medical documents, Europarl.

- Results (WSR↓, MAR↓):

TASK		Prefix				Segment	
		WSR		MAR		WSR	MAR
		NMT	PB-SMT	NMT	PB-SMT	NMT	
XRCE	En→Ge	56.5	61.3	11.2	13.8	54.7	16.0
	En→Fr	49.4	50.7	12.0	13.8	48.1	15.4
UFAL	En→Ge	51.3	70.3	7.8	12.4	50.4	15.1
	En→Fr	33.7	51.7	6.4	11.0	26.8	9.8
Europarl	En→Ge	55.4	75.4	10.1	16.1	52.9	15.9
	En→Fr	47.2	72.0	9.9	17.0	45.3	14.1

Other tasks

English to Chinese



Japanese to English

Other IMT topics

- Other types of interactions
  - Active mouse
  - Passive vs active interaction: Use of word confidence measures (IBM1)
  - Other input modalities: speech, e-pen
  - Future input modality: gaze-tracking
  - We need more realistic user models!

Demos

- *TransType* http://rali.iro.umontreal.ca/rali/?q=en/node/1282
- CasMaCat: https://demosmt.prhlt.upv.es/matecat-test/translate/demo-eutt2.xliff/es/1-fmttqpvc/demo@4002#1
- INMT: https://demosmt.prhlt.upv.es/inmt/

One theoretical issue

[Alabau et al. PRL 2012]

- What function optimizes the rule used for IMT?

$$\hat{\mathsf{y}}_s = \underset{\mathsf{y}_s}{\operatorname{argmax}}\ p(\mathsf{y}_s \mid \mathsf{x}, \mathsf{y}_p) \qquad (1)$$

  and the complete hypothesis in an iteration is $\mathsf{y} = \mathsf{y}_p\hat{\mathsf{y}}_s$

- For IMT, the following rule minimize the number of iterations (based on [Oncina PRL 2009]):

$$\hat{y} = \underset{y}{\operatorname{argmax}} \sum_{\mathsf{y}_s} p(y, \mathsf{y}_s \mid \mathsf{x}, \mathsf{y}_p) \qquad (2)$$

  and the prefix of the hypothesis in an iteration is $\mathsf{y} = \mathsf{y}_p\hat{y}$

- The rule used in (1) is a max approximation of (2)

- In practice, experimental results show that the improvements are marginal in IMT.

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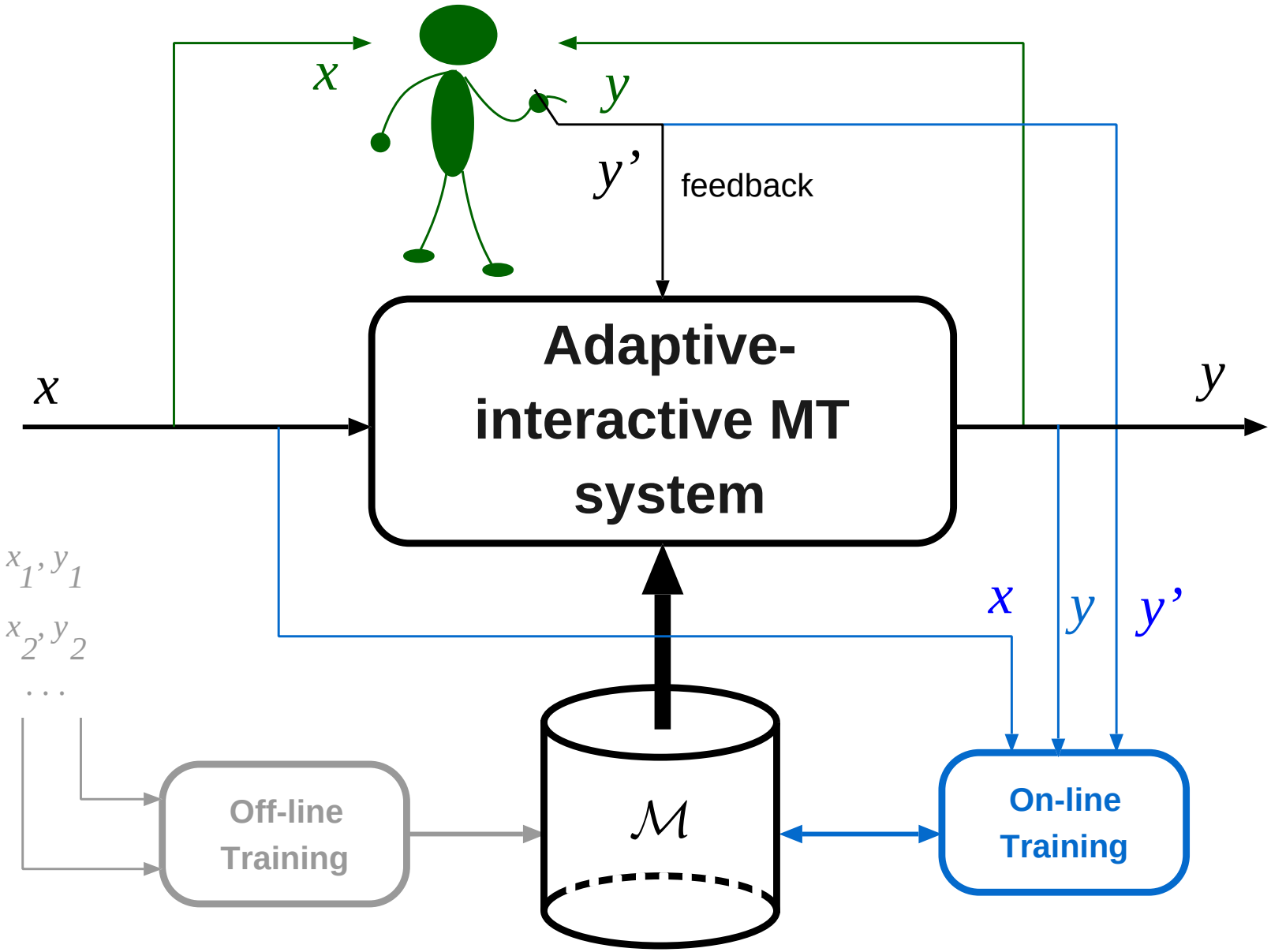
Adaptive training

- *Human interaction* offers another unique opportunity to improve IMT system's behavior by tuning the translation models.

- In each iteration, the text obtained by means of additional user keystrokes to correct the suggestion produced by the IMT systems together with the corresponding aligned source segments can generally be converted into new, fresh training data, useful for *adapting* the system to changing environment.

Diagram of an interactive MT system: Adaptation



Some techniques for adaptation in IMT

- In the TT framework, a *cache technique* both for language models (unigrams, bigrams and trigrams) and translation models (model IBM1 and IBM2) is used [Nepveu et al. EMNLP 2004]
- The output of post-editing has been used for adaptation [Callison-Burch et al. EAMT 2004] [Domingo et al. EAMT 2020]
- Another technique is based on *translation memories*, in order to store the data corrected by the human [Biçini & Dymetman CICling 08]
- Techniques for topic-adaptation in statistical machine translation: Bayesian adaptation ([Sanchis & Casacuberta CSL 2015]), infrequent n-grams, etc.
- On-line learning: incremental EM, Perceptron, passive-aggressive, etc.
- Active learning = On-line learning + active interaction (at sentence level)

On-line learning

$$\hat{\mathsf{y}}_s = \underset{\mathsf{y}_s}{\operatorname{argmax}}\ p(\mathsf{y}_p \mathsf{y}_s \mid \mathsf{x}; \boldsymbol{\theta})$$

- Using a PB-based NT system:

$$p(\mathsf{y} \mid \mathsf{x}; \boldsymbol{\theta}) = \frac{\exp\left(\sum_{m=1}^{M} \lambda_m h_m(\mathsf{x}, \mathsf{y})\right)}{\sum_{\mathsf{y}'} \exp\left(\sum_{m=1}^{M} \lambda_m h_m(\mathsf{x}, \mathsf{y}')\right)}$$

  where $\boldsymbol{\theta}$:

  - The weights of the log-linear models $\lambda_k \Rightarrow$ On-line learning the weights.
  - The parameters θ_k of each feature $h_k \Rightarrow$ On-line learning the parameters.

- Using LSTMs or GRUs or Transformer:

$$p(\mathsf{y} \mid \mathsf{x}; \boldsymbol{\theta}) = \prod_{i=1}^{|\mathsf{y}|} p(y_i \mid y_1^{i-1}, \mathbf{c}(\mathsf{x}); \boldsymbol{\theta})$$

  $\boldsymbol{\theta}$: the weights of the LSTMs and Transformer $\Rightarrow$ On-line learning the parameters.

On-line learning the weights of a PB-based MT system

- Different techniques can be used: simplified Perceptron [España & Márquez, EAMT 2008], passive-aggressive [Cesa-Bianch et al. SMART 2008][Martinez et al. IbPRIA 2011], discriminative ridge regression [Martinez et al. PR 2012], Bayesian adaptation [Sanchis CSL 15]. ...

- Discriminative ridge regression:
  - Good hypotheses within a n-best list score higher, bad hypotheses lower.
  - Correlation between difference in translation quality and difference in score.

- In a PE scenario (quality=TER): the best results (2 TER points) with discriminative ridge regression [Martinez et al. PR 2012]

- In an IMT scenario (quality=KSR): No improvements or marginals [Chinea et al. CSL 2019]

On-line learning the features of a PB-based MT system

[Ortiz CL 2016]

- Given a new sentence pair (x, y) validated by the user, the model of each feature is updated.
- To do this, a set of sufficient statistics that can be incrementally updated is maintained for each feature function $h_k(\mathrm{x}, \mathrm{a}, \mathrm{y})$.
- Standard estimation procedures use word alignment matrices to extract phrase counts (HMM models)
- Estimation of HMM models is based on the incremental EM algorithm.
- Clear improvements are achieved w.r.t. not perform the update.
- The Thot toolkit implements a fully fledged phrase-based SMT system https://github.com/daormar/thot/.

On-line learning the parameters of a NMT system

[Peris et al. CSL 2019]

- Given a new sentence pair (x, y) validated by the user, the weights of the model are updated.
- To do this, one iteration of the ADAGRAD or ADADELTA is performed.
- An increase of 2-3 BLUE points w.r.t. not perform the update.
- The toolkit implements a fully NMT SMT system
  https://github.com/lvapeab/nmt-keras

On-line learning INMT experimental results with Transformer

[Peris 2019]

- In-domain and out-of-domain corpora.
- Train on out-of-domain (Europarl), fine-tune with in-domain.

TASK		TER[↓]		BLEU[↑]		KSMR[↓]	
		Static	Adaptative	Static	Adaptative	Static	Adaptative
XRCE	En→Ge	58.4	49.8	27.9	36.4	22.9	20.0
	En→Fr	48.1	41.1	41.1	47.9	21.8	18.2
UFAL	En→Ge	59.0	56.2	22.7	24.6	24.8	23.4
	En→Fr	47.4	41.5	36.4	41.7	17.0	15.9

On-line learning INMT experimental results with Transformer

[Peris 2019]

- Lack in-domain data.
- Train on out-of-domain corpora (Europarl).

TASK		TER[↓]		BLEU[↑]		KSMR[↓]	
		Static	Adaptative	Static	Adaptative	Static	Adaptative
XRCE	En→Ge	80.0	78.0	6.4	10.5	51.8	42.9
	En→Fr	78.0	68.1	14.5	20.5	54.0	41.6
UFAL	En→Ge	67.5	62.4	15.9	18.7	30.8	28.1
	En→Fr	53.1	49.8	29.1	33.2	25.4	22.8

On-line learning PE experimental results with professional translators

[Peris 2019]

- Only post-editing.
- En→Sp, UFAL.
- Two test sets (T1 and T2) of 150 sentences,
- Training with WMT'13. No in-domain data.

Test data	System	Words per hour[↑]	hTER[↓]	hBLEU[↑]
T1	Static	1581	39.5	37.3
	Adaptive	2096	34.2	55.1
T2	Static	2091	38.4	45.7
	Adaptive	2149	34.2	50.5

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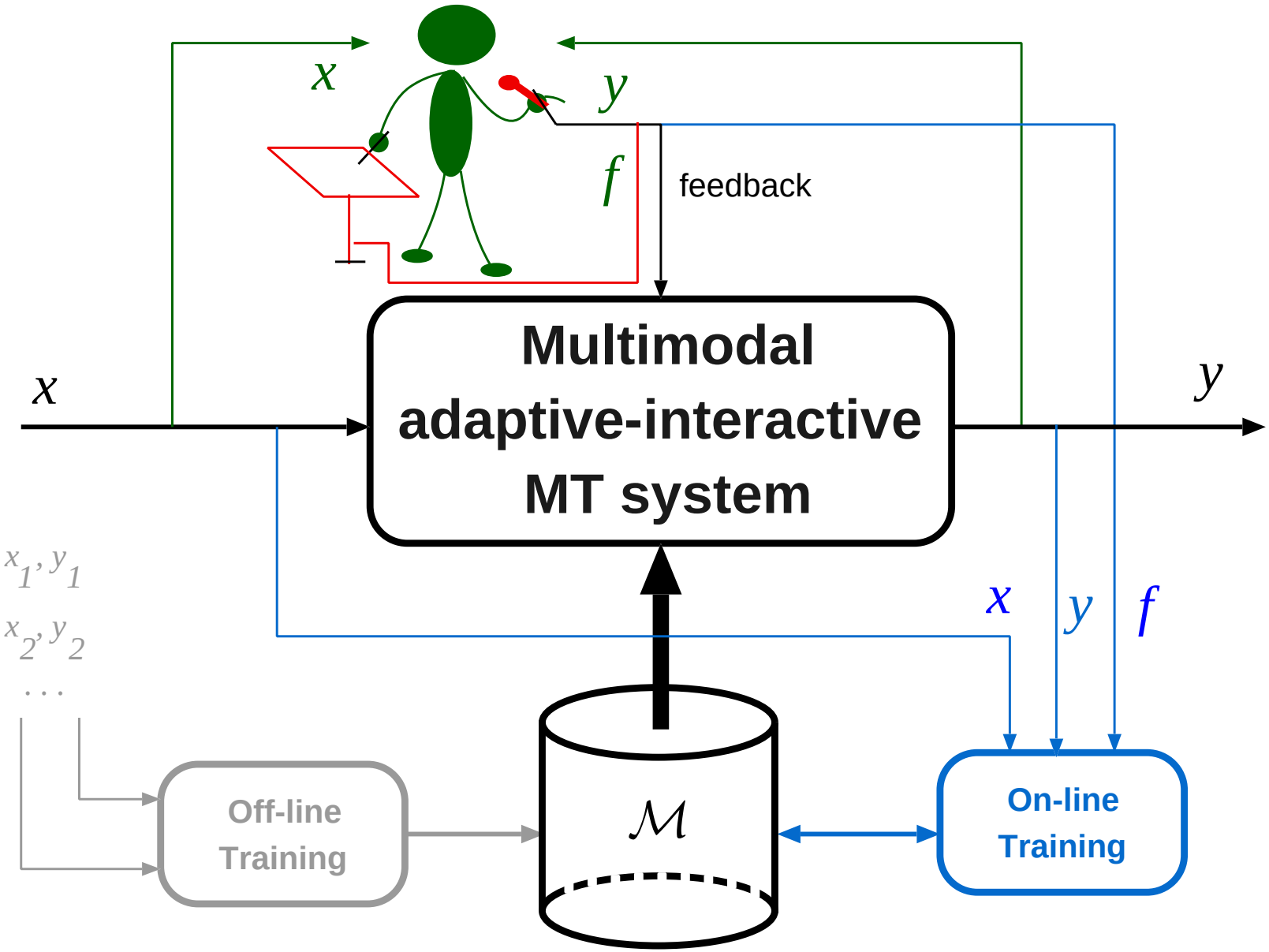
Other information sources for IMT

- Using speech recognition in IMT (In this section)
- Using e-pen for gesture and handwriting text recognition (In this section)
- Exploiting visual supports (viewgraphs, etc.) (In the future)
- Gaze tracking (In the future)

Diagram of an interactive MT system: Multi-modality



Using speech recognition in IMT

Early idea: a human translator dictates aloud the translation in the *target language*. As the source text is known by the system, this knowledge can be used to reduce recognition errors.

TransTalk project [Dymetman et al. ICSLP 1994] [Brown et al. CSL 1994]) [Khadivi et al. COLING-ACL 2006] [Paulik et al. MELECON 2006]).

Using speech recognition in IMT

Alternative idea within the IMT framework: the human translator determines acceptable prefixes of the suggestions made by the system by reading (with possible modifications) parts of these suggestions (*TransType 2* project [Vidal et al. IEEE TASLP 2006]).

- A much lower degree of freedom is possible and the correspondingly lower perplexity allows for sufficiently high recognition accuracy.
- As this is fully integrated within the IMT paradigm, the user can make use of the conventional means (keyboard and/or mouse) to guarantee that the produced text exhibits an adequate level of quality.

Use of speech recognition in IMT

- Let x be the source text and y_p a "correct" prefix of the target sentence. As in pure text IMT the system suggests an optimal suffix:

$$\hat{\mathsf{y}}_s = \operatorname*{argmax}_{t_s} p(\mathsf{y}_s \mid \mathsf{x}, \mathsf{y}_p)$$

- The user is now allowed to *utter some words*, v, generally aimed at amending parts of $\hat{\mathsf{y}}_s$ and the system has then to obtain a most probable decoding of v [Vidal et al. IEEE TASLP 2006]:

$$\hat{\mathbf{d}} = \operatorname*{argmax}_{\mathbf{d}} p(\mathbf{d} \mid \mathsf{x}, \mathsf{y}_p, \hat{\mathsf{y}}_s, \mathsf{v}) = \operatorname*{argmax}_{\mathbf{d}} p(\mathsf{v} \mid \mathbf{d})\, p(\mathbf{d} \mid \mathsf{x}, \mathsf{y}_p, \hat{\mathsf{y}}_s)$$

- Finally, the user can enter additional amendment keystrokes k, to produce a new consolidated prefix, y_p, based on the previous y_p, $\hat{\mathbf{d}}$, k and parts of $\hat{\mathsf{y}}_s$.
- Exerimental results with XEROX corpus show important WER improvements from simple speech recognition to the more constrained scenarios.

Example of speech-enabled IMT human-machine interaction

Translating the source sentence (x) *"Click OK to close the print dialog"* into Spanish (The reference sentence is *"Haga clic en ACEPTAR para cerrar el cuadro de diálogo de impresión"*):

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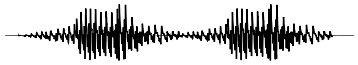
User (v): 

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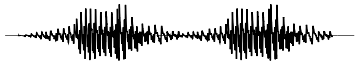
User (v): 

Decoding (**d**): Haga clic a

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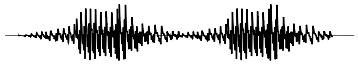
User (v): 

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User (y_p): Haga clic **en ACEPTAR**

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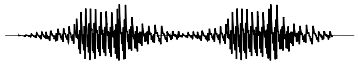
User (v): 

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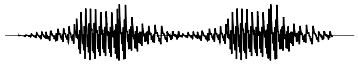
User (v): 

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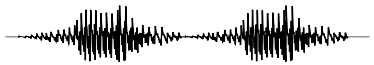
User (v): 

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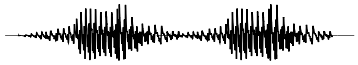
User (v): 

Decoding (**d**): Haga clic a

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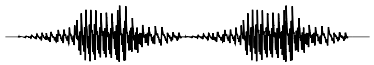
System ($\hat{y}_s$): para cerrar el diálogo de impresión

User (v): 

Decoding (**d**): cerrar el cuadro

User (y_p): Haga clic en ACEPTAR para cerrar el cuadro↑

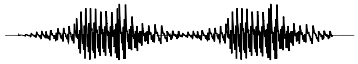
System ($\hat{y}_s$): de diálogo de impresión

User (y_p): Haga clic en ACEPTAR para cerrar el cuadro de diálogo de impresión↕

Example of speech-enabled IMT human-machine interaction

Translating the source sentence (x) *"Click OK to close the print dialog"* into Spanish
(The reference sentence is *"Haga clic en ACEPTAR para cerrar el cuadro de diálogo de impresión"*):

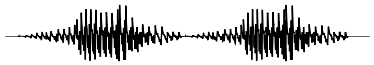
System ($\hat{y}_s$): Haga clic para cerrar el diálogo de impresión

User (v): 

Decoding (**d**): Haga clic a

User (y_p): Haga clic **en ACEPTAR**

System ($\hat{y}_s$): para cerrar el diálogo de impresión

User (v): 

Decoding (**d**): cerrar el cuadro

User (y_p): Haga clic en ACEPTAR para cerrar el cuadro↑

System ($\hat{y}_s$): de diálogo de impresión

User (y_p): Haga clic en ACEPTAR para cerrar el cuadro de diálogo de impresión↕

Output ($\hat{y}$): Haga clic en ACEPTAR para cerrar el cuadro de diálogo de impresión

CasMaCat interface with e-pen

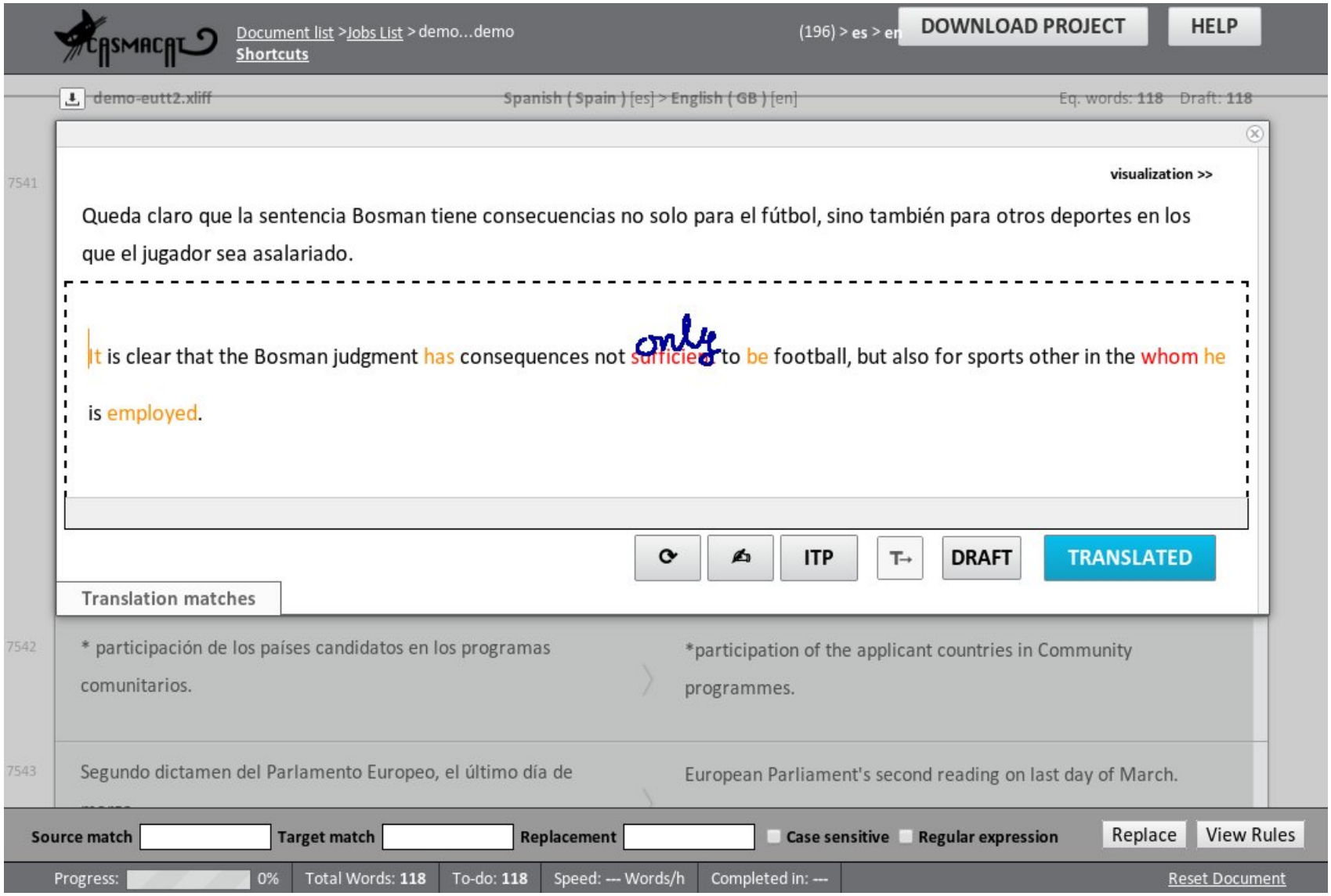
[Alabau et al. PRJ 2014]

- E-pen based interaction is a promising alternative to keyboard and mouse.q
- Recognition errors could reduce productivity w.r.t. keyboard, but rule of thumb to user acceptability is $5\% \sim 20\%$ acceptable if there is a substantial payoff in terms of achieving task goals.
- Aiming at a more comfortable system:
  - Recognition of sub-word units and sequences of multiple words.
  - Recognition of e-pen gestures.
- Simmilar to the case of the speech modality

$$\hat{\mathbf{d}} = \underset{\mathbf{d}}{\operatorname{argmax}}\, p(\mathbf{d} \mid \mathsf{x}, \mathsf{y}_p, \hat{\mathsf{y}}_s, \mathsf{v}) = \underset{\mathbf{d}}{\operatorname{argmax}}\, p(\mathsf{v} \mid \mathbf{d})\; p(\mathbf{d} \mid \mathsf{y}_p, \mathsf{x})$$

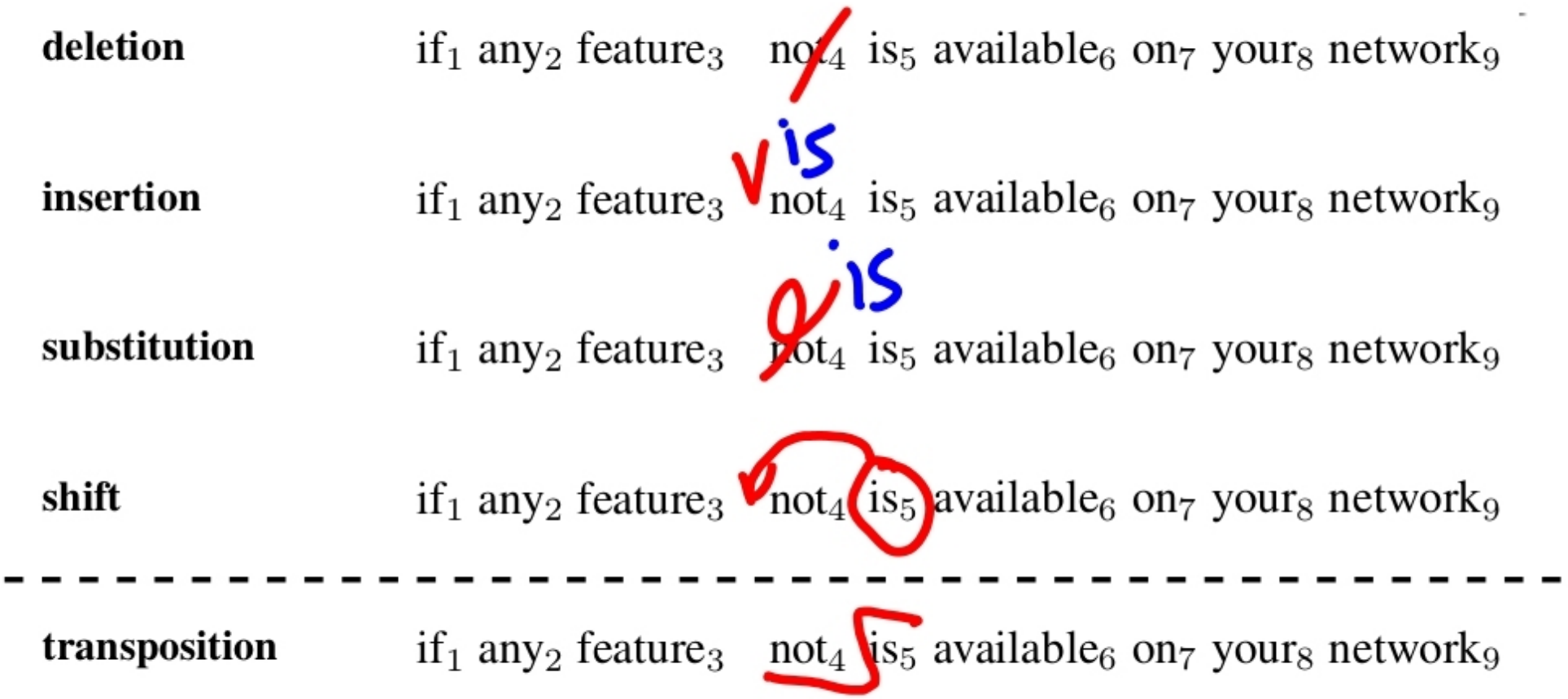
- Lab experimental results show that the use of translation models allows for an important improvement in CER with respect a standard HTR system.

CasMaCat interface with e-pen



Proof-reading gestures

[Alabau et al. PRJ 2014]



Error rate with state-of-the-art gesture recognizer $\approx 10\%$

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  `http://www.casmacat.eu/`
- Other related projects:
  - Matecat `http://www.matecat.com/`
  - Faust `http://divf.eng.cam.ac.uk/faust`
  - QT21 `http://www.qt21.eu/`