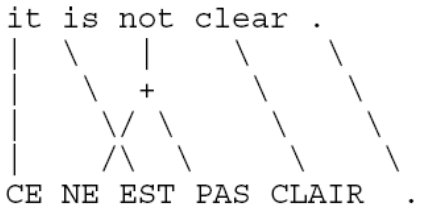
# Statistical NLP
## Spring 2010


Lecture 18: Phrase / Syntactic MT

Dan Klein – UC Berkeley

# Decoding

- First, consider word-to-word models
  - Finding best alignments is easy
  - Finding translations is hard (why?)



# Bag "Generation" (Decoding)

*Exact reconstruction* (24 of 38)

Please give me your response as soon as possible.
⇒ Please give me your response as soon as possible.

*Reconstruction preserving meaning* (8 of 38)

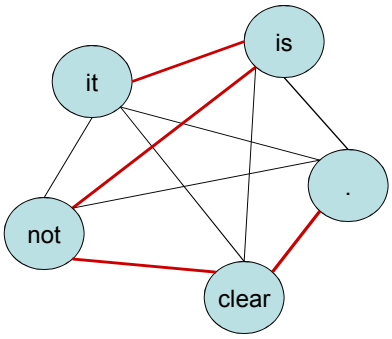
Now let me mention some of the disadvantages.
⇒ Let me mention some of the disadvantages now.

*Garbage reconstruction* (6 of 38)

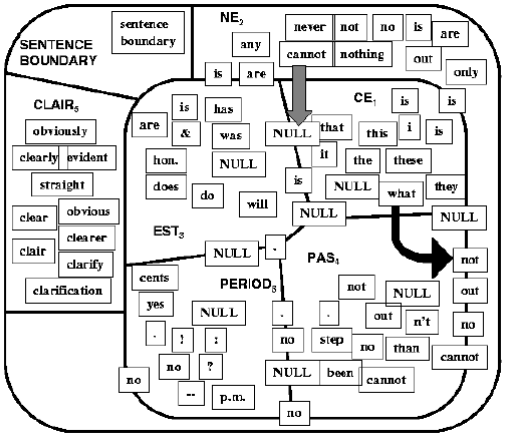
In our organization research has two missions.
⇒ In our missions research organization has two.

# Bag Generation as a TSP

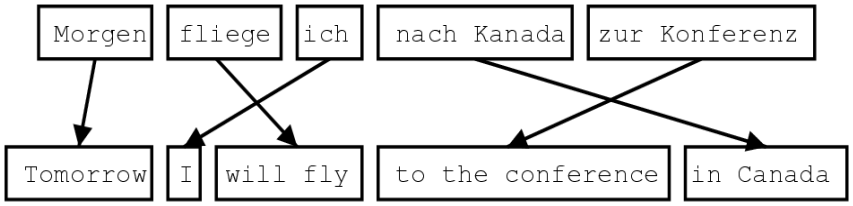
- Imagine bag generation with a bigram LM
  - Words are nodes
  - Edge weights are P(w|w')
  - Valid sentences are Hamiltonian paths
- Not the best news for word-based MT (and it doesn't get better with phrases)

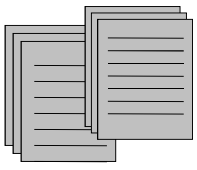


# IBM Decoding as a TSP

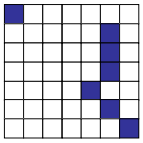



# Phrase-Based Systems



Sentence-aligned corpus



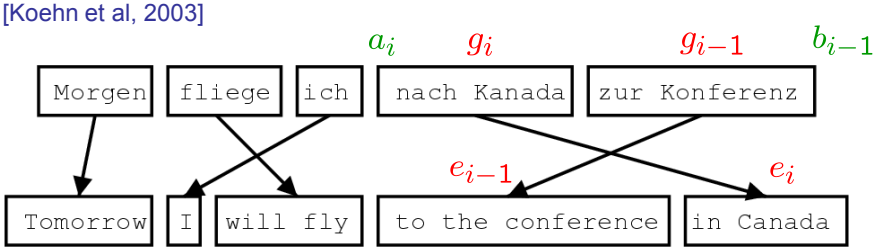
Word alignments

```
cat ||| chat ||| 0.9
the cat ||| le chat ||| 0.8
dog ||| chien ||| 0.8
house ||| maison ||| 0.6
my house ||| ma maison ||| 0.9
language ||| langue ||| 0.9
…
```

Phrase table (translation model)

# The Pharaoh "Model"

[Koehn et al, 2003]




$$P(e|g) = P(\{\bar{g}_i\}|g) \prod_i \phi(\bar{e}_i|\bar{g}_i) d(a_i - b_{i-1})$$

Segmentation — Translation — Distortion

# The Pharaoh "Model"

$$P(f|e) = P(\{\bar{e}_i\}|e) \prod_i \phi(\bar{f}_i|\bar{e}_i) d(a_i - b_{i-1})$$

$\frac{1}{K}$ — $\frac{count(\bar{f}_i, \bar{e}_i)}{count(\bar{e}_i)}$ — $\alpha^{|a_i - b_{i-1}|}$

*Where do we get these counts?*

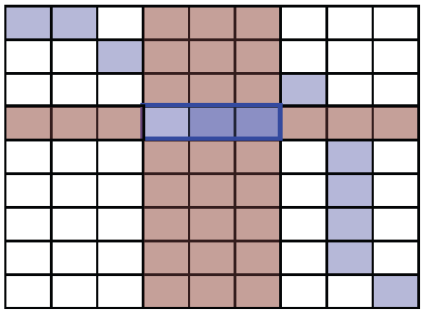
# Counting Phrase Pairs

**Input:**

Gracias , lo haré de muy buen grado .
Thank you , I shall do so gladly .

*First, we learn word alignments,*

*then we infer aligned phrases.*



| Gloss | |
|---|---|
| Gracias | *Thanks* |
| , | *,* |
| lo | *that* |
| haré | *do [first; future]* |
| de | *of* |
| muy | *very* |
| buen | *good* |
| grado | *degree* |
| . | *.* |

Thank you , I shall do so gladly .

# Phrase-Based Decoding

这 | 7人 | 中包括 | 来自 | 法国 | 和 | 俄罗斯 | 的 | 宇航 | 员 | .

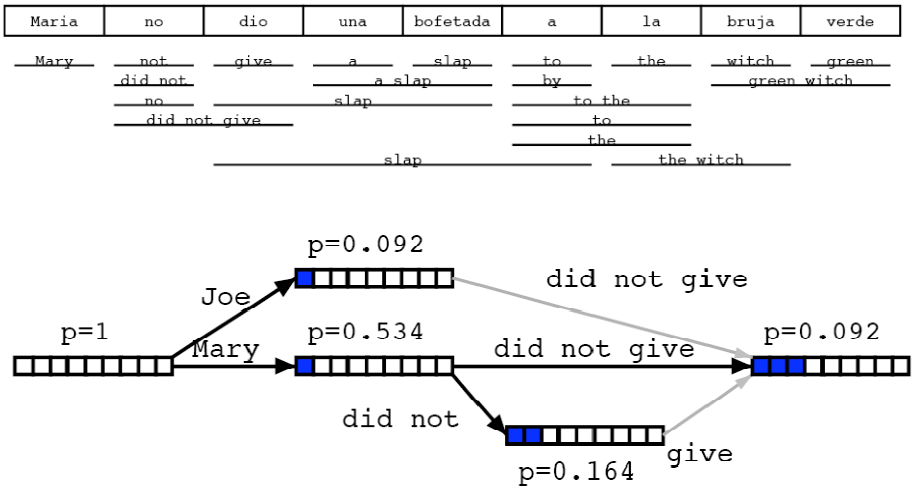
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **the** | 7 people | including | by some | | **and** | the russian | **the** | the astronauts | | , |
| it | 7 people included | | by france | | and the | the russian | | international astronautical | of rapporteur . | |
| this | 7 out | including the | **from** | the french | and the russian | | the fifth | | . | |
| these | 7 among | including from | | the french and | | of the russian | of | space | members | . |
| that | 7 persons | including from the | | of france | and to | russian | of the | aerospace | members . | |
| | 7 include | | from the | of france and | | russian | | **astronauts** | | . the |
| | 7 numbers include | | **from france** | | and russian | | of astronauts who | | | . " |
| | 7 populations include | | those from france | | and russian | | | astronauts . | | |
| | 7 deportees included | | come from | **france** | **and russia** | | in | astronautical | personnel | ; |
| | 7 philtrum | including those from | | **france and** | | **russia** | a space | | **member** | |
| | | including representatives from | | france and the | | **russia** | | astronaut | | |
| | | include | came from | **france and russia** | | | by cosmonauts | | | |
| | | include representatives from | | french | **and russia** | | | cosmonauts | | |
| | | include | came from france | | and russia 's | | | cosmonauts . | | |
| | | **includes** | coming from | french and | | russia 's | | cosmonaut | | |
| | | | | french and russian | | | 's | astronavigation | member . | |
| | | | | french | **and russia** | | **astronauts** | | | |
| | | | | | and russia 's | | | | special rapporteur | |
| | | | | | , and | **russia** | | | rapporteur | |
| | | | | | , and russia | | | | rapporteur . | |
| | | | | | , and russia | | | | | |
| | | | | | or | russia 's | | | | |

Decoder design is important: [Koehn et al. 03]

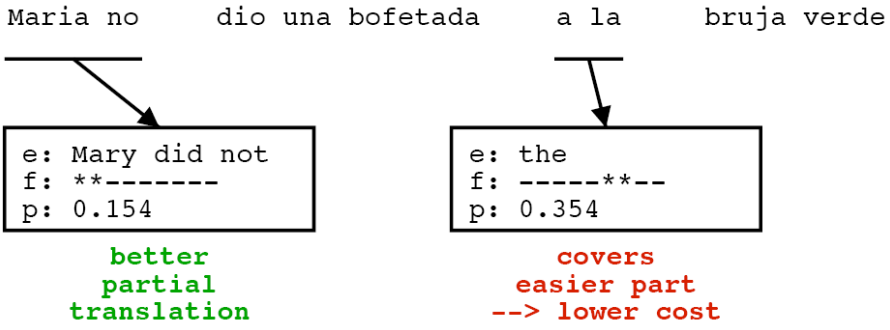
# The Pharaoh Decoder


- Probabilities at each step include LM and TM

# Hypotheis Lattices



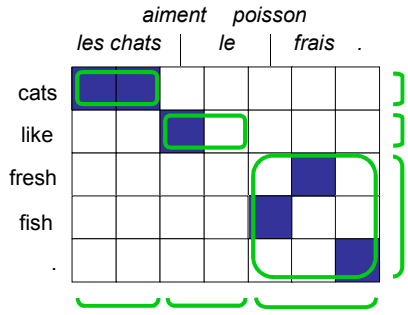
# Pruning




- Problem: easy partial analyses are cheaper
  - Solution 1: use beams per foreign subset
  - Solution 2: estimate forward costs (A*-like)

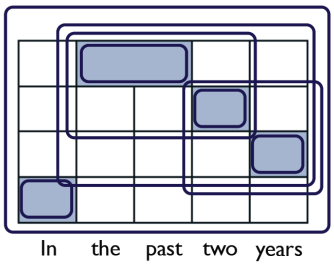
# Phrase Scoring

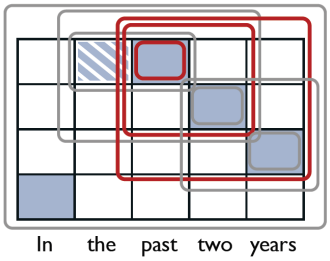
$$\phi_{new}(\bar{e}_j|\bar{f}_i) = \frac{c(\bar{f}_i, \bar{e}_j)}{c(\bar{f}_i)}$$




- Learning weights has been tried, several times:
  - [Marcu and Wong, 02]
  - [DeNero et al, 06]
  - … and others
- Seems not to work well, for a variety of partially understood reasons
- Main issue: big chunks get all the weight, obvious priors don't help
  - Though, [DeNero et al 08]

# Extraction Sets



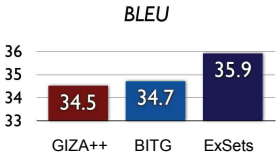

过去 [past]
两 [two]
年 [year]
中 [in]

$$\phi(\mathcal{A}) = \sum_{(i,j)\in\mathcal{A}_s} \phi(i,j) + \sum_{[g,h]\Leftrightarrow[k,\ell]\ \in R_n(\mathcal{A})} \phi(g,h,k,\ell)$$

P(in|中) = 0.8
InDictionary = 1.0

Count(*the past two years*, 过去 两 年 ) = 7
Size(4,3) = 1

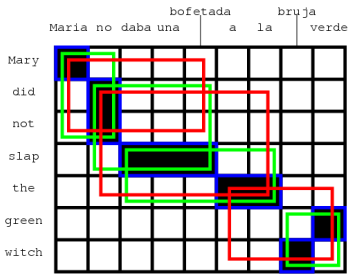
Translation quality for Chinese-to-English

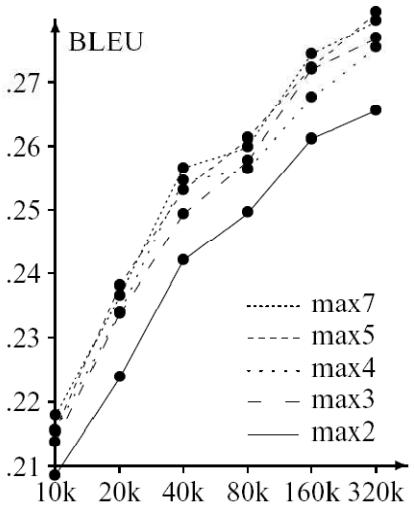



[DeNero and Klein, in submission]

# Phrase Size

- Phrases do help
  - But they don't need to be long
  - Why should this be?



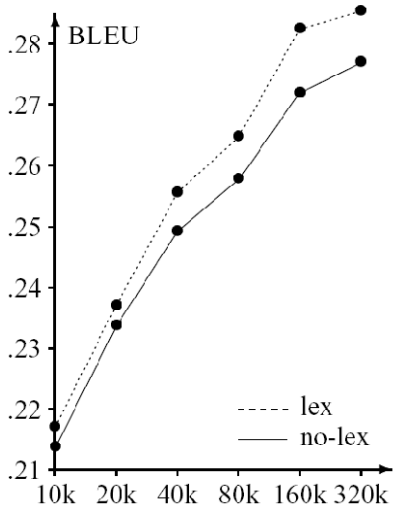



# Lexical Weighting

$$\phi(\bar{f}_i|\bar{e}_i) = \frac{count(\bar{f}_i, \bar{e}_i)}{count(\bar{e}_i)} p_w(\bar{f}_i|\bar{e}_i)$$

| | f1 | f2 | f3 |
|---|---|---|---|
| NULL | -- | -- | ## |
| e1 | ## | -- | -- |
| e2 | -- | ## | -- |
| e3 | -- | ## | -- |

$$\begin{aligned} p_w(\bar{f}|\bar{e}, a) &= p_w(f_1 f_2 f_3|e_1 e_2 e_3, a) \\ &= w(f_1|e_1) \\ &\quad \times \frac{1}{2}(w(f_2|e_2) + w(f_2|e_3)) \\ &\quad \times w(f_3|\text{NULL}) \end{aligned}$$



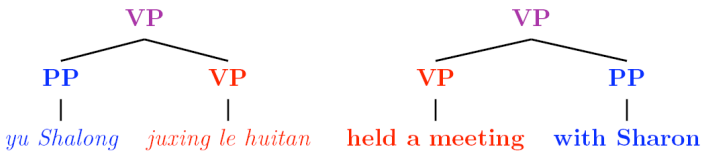

# WSD?

- Remember when we discussed WSD?
  - Word-based MT systems rarely have a WSD step
  - Why not?

# Syntax-Based MT

- synchronous context-free grammars (SCFGs)
  - context-free grammar in two dimensions
  - generating pairs of strings/trees simultaneously
  - co-indexed nonterminal further rewritten as a unit

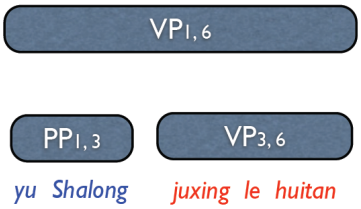
$$\begin{array}{lcll} \text{VP} & \rightarrow & \text{PP}^{(1)}\ \text{VP}^{(2)}, & \text{VP}^{(2)}\ \text{PP}^{(1)} \\ \text{VP} & \rightarrow & \textit{juxing le huitan}, & \text{held a meeting} \\ \text{PP} & \rightarrow & \textit{yu Shalong}, & \text{with Sharon} \end{array}$$




# Translation by Parsing

- translation with SCFGs => monolingual parsing
- parse the source input with the source projection
  - build the corresponding target sub-strings in parallel

$$\begin{array}{lcl} \text{VP} & \rightarrow & \text{PP}^{(1)}\ \text{VP}^{(2)}, \\ \text{VP} & \rightarrow & \textit{juxing le huitan}, \\ \text{PP} & \rightarrow & \textit{yu Shalong}, \end{array}$$



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$\text{VP} \rightarrow \text{PP}^{(1)}\ \text{VP}^{(2)},$ $\text{VP}^{(2)}\ \text{PP}^{(1)}$
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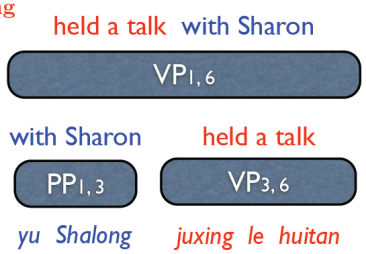
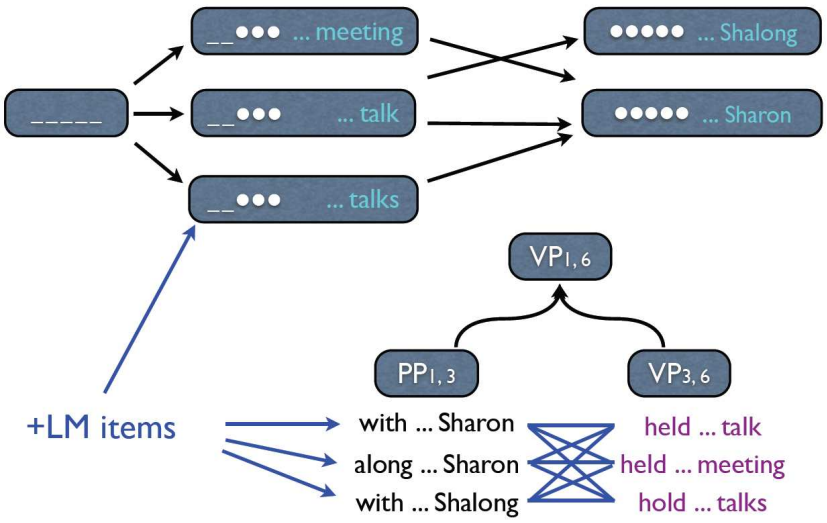



# Compact Forests



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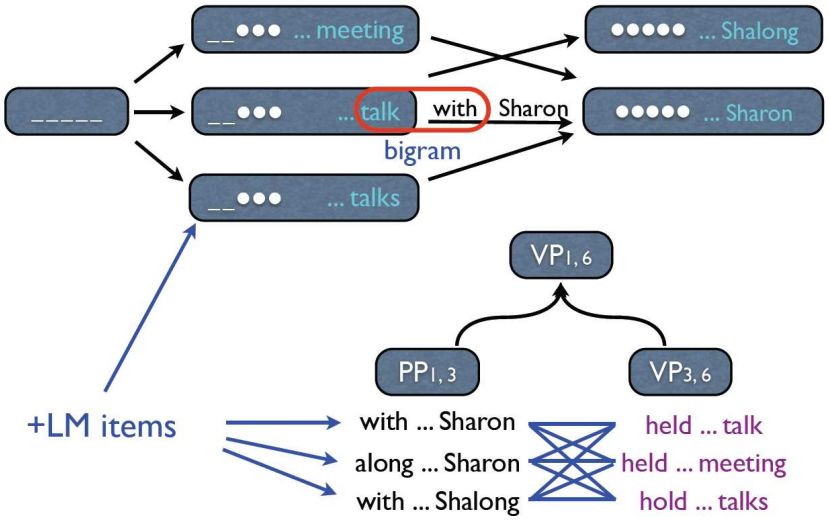


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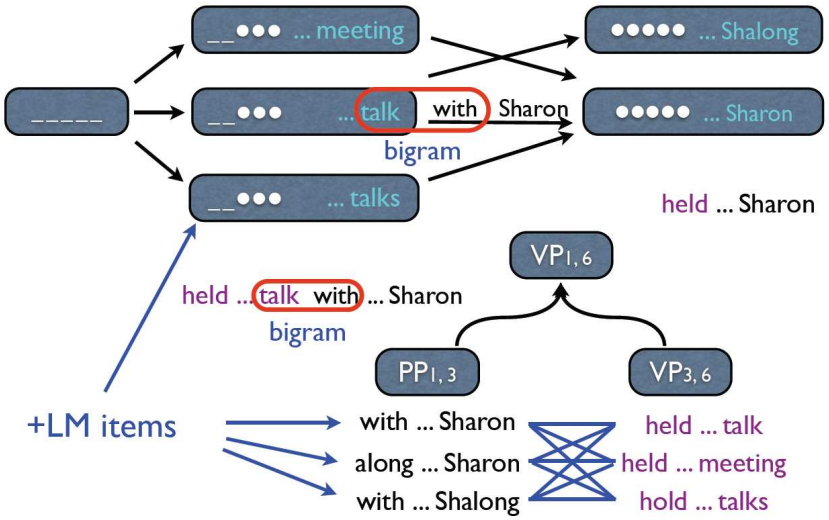

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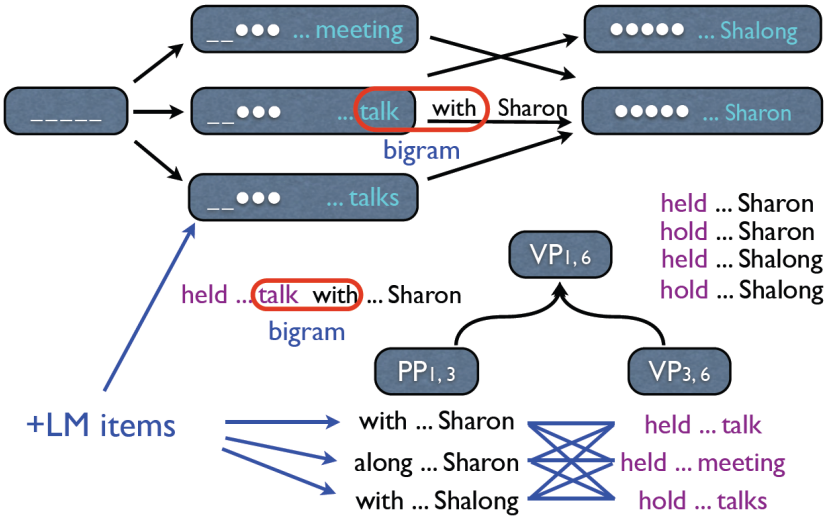
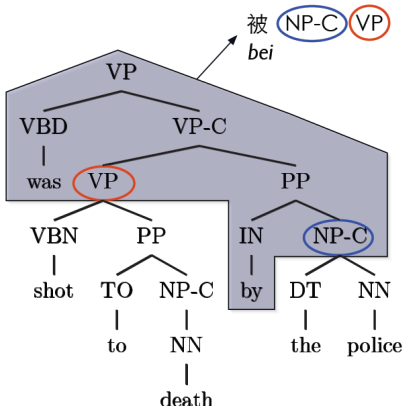



# Learning MT Grammars

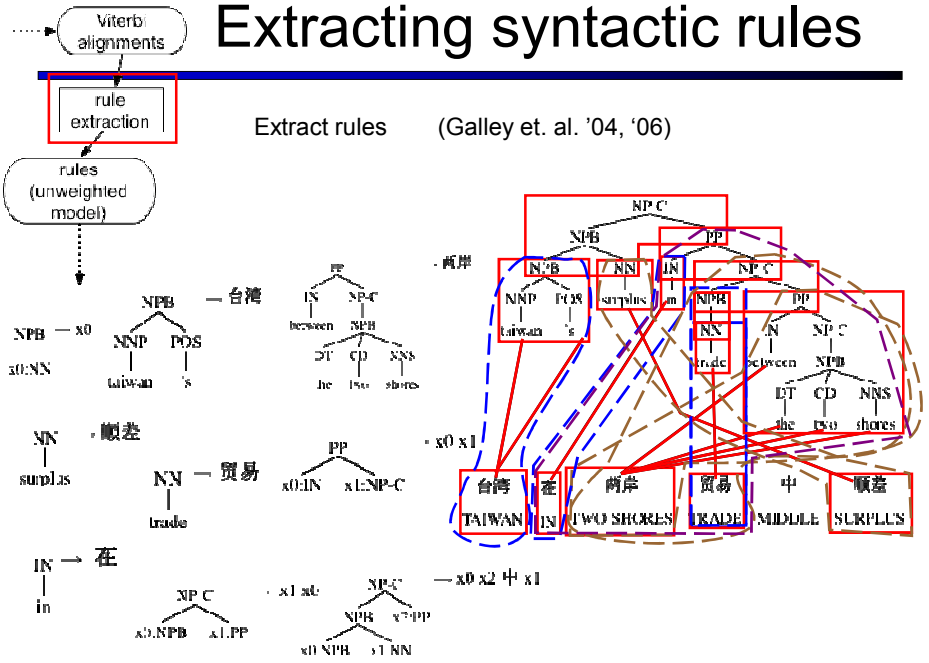
- syntax-directed, English to Chinese (Huang, Knight, Joshi, 2006)
- first parse input, and then recursively transfer



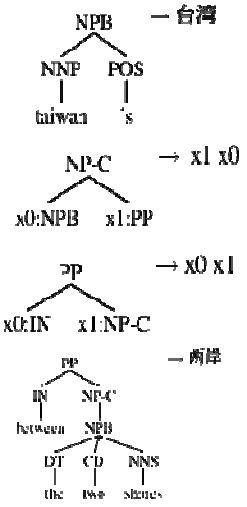

synchronous tree-substitution grammars (STSG)

(Galley et al., 2004; Eisner, 2003)

# Extracting syntactic rules

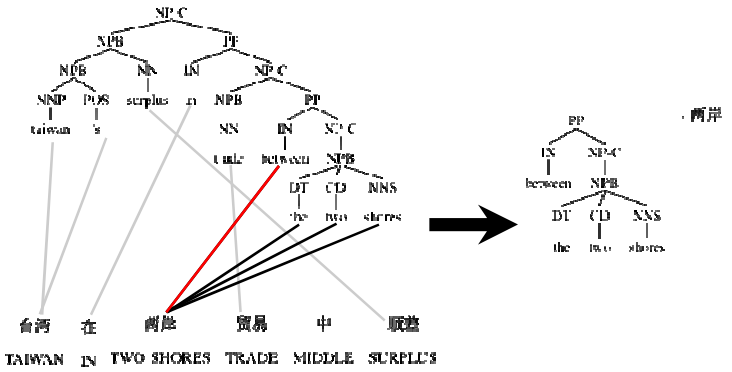



# Rules can...



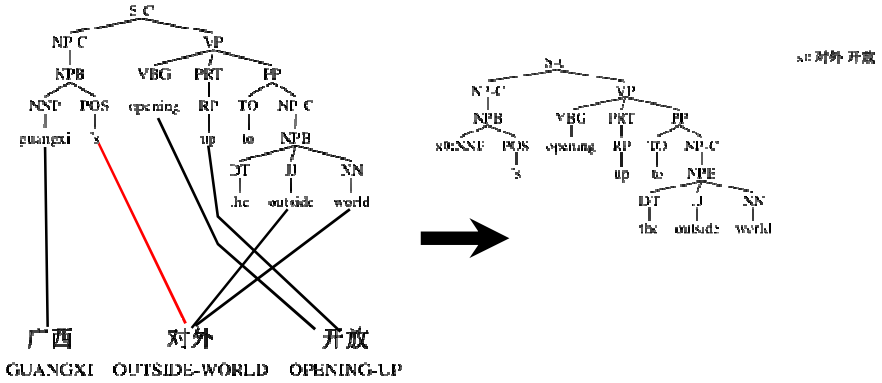

- capture phrasal translation
- reorder parts of the tree
- traverse the tree without reordering
- insert (and delete) words

# Bad alignments make bad rules



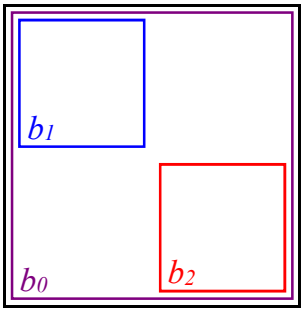

This isn't very good, but let's look at a worse example...

# Sometimes they're really bad




One bad link makes a totally unusable rule!

# Discriminative Block ITG




Features

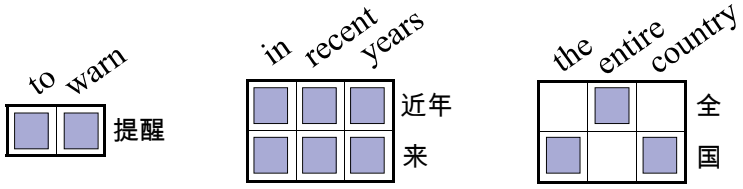
$\varphi(\ b_0, s, s'\ )$

$\varphi(\ b_1, s, s'\ )$

$\varphi(\ b_2, s, s'\ )$

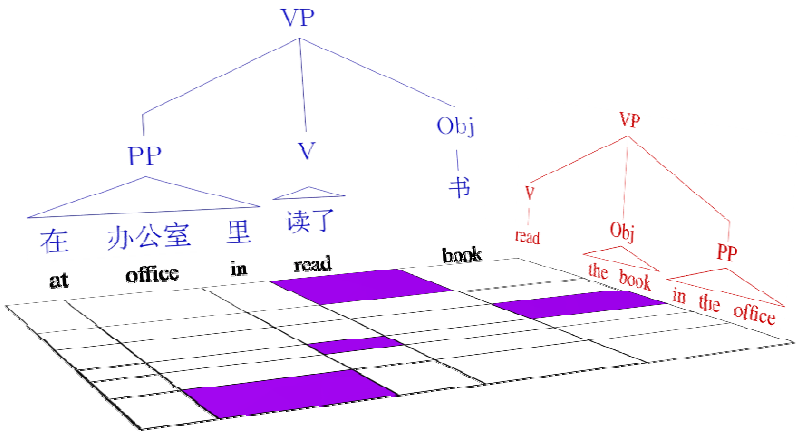
$$\phi(\mathcal{A}) = \sum_{b \in \mathcal{A}} \phi(b, s, s')$$

$$P(\mathcal{A}) \propto \exp\langle \theta, \phi(\mathcal{A}) \rangle$$



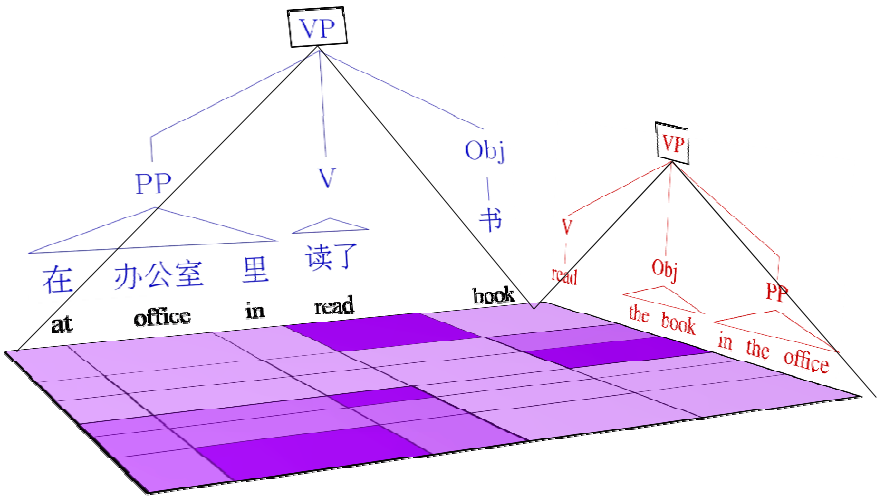

[Haghighi, Blitzer, Denero, and Klein, ACL 09]

# Syntactic Correspondence




Build a model $p_\theta$ ( ▲, ▲, ▦ | 中文, EN )

# Synchronous Grammars?

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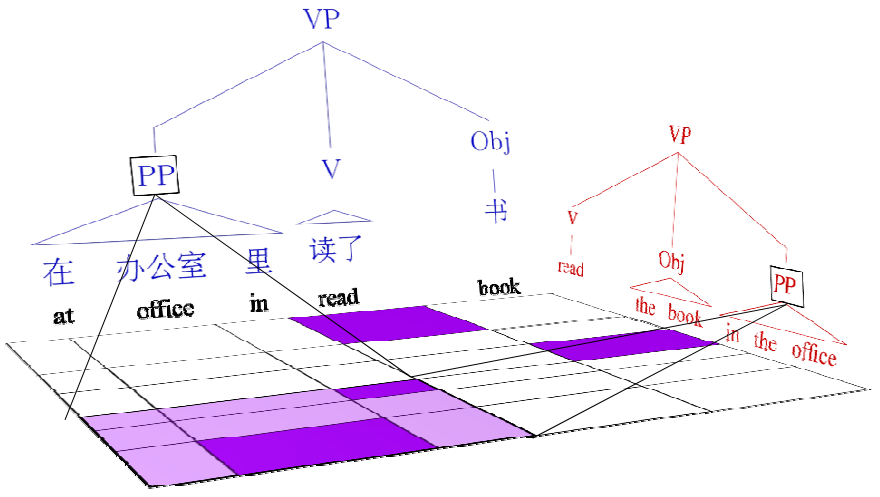

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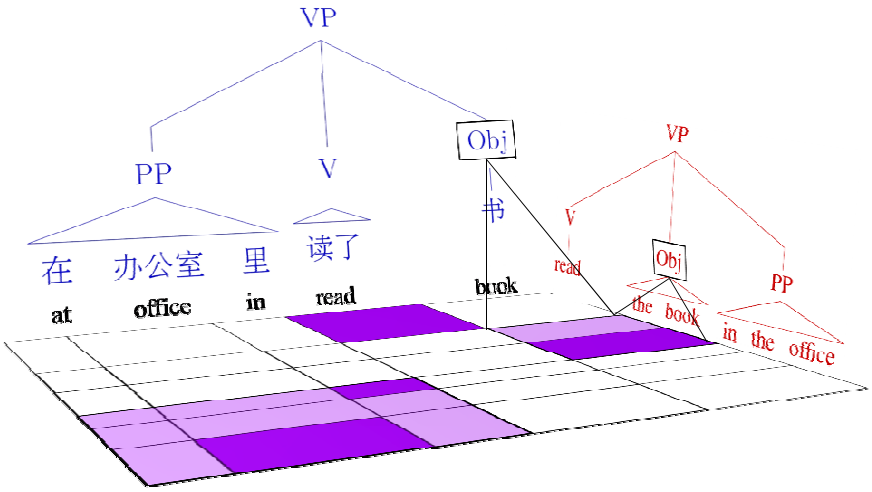
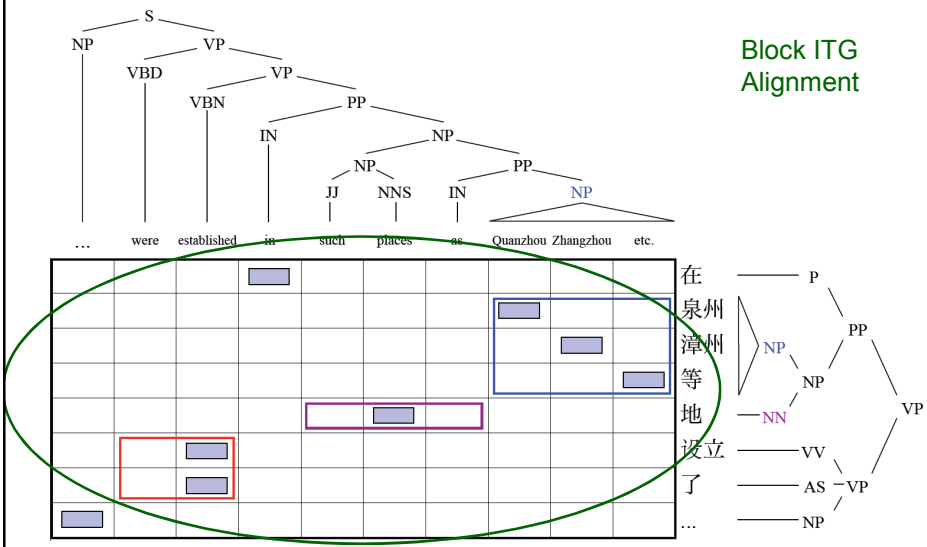



# Adding Syntax: Weak Synchronization

Block ITG Alignment



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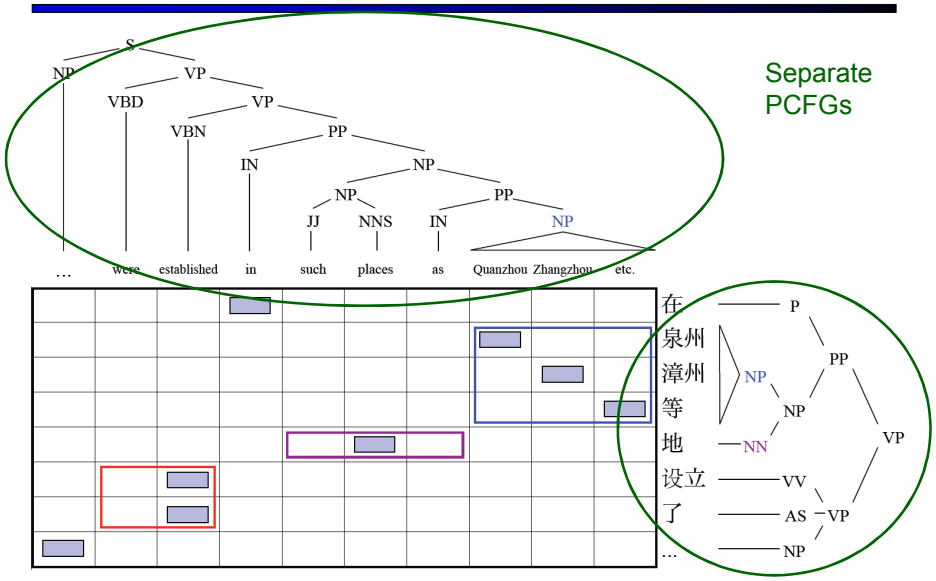
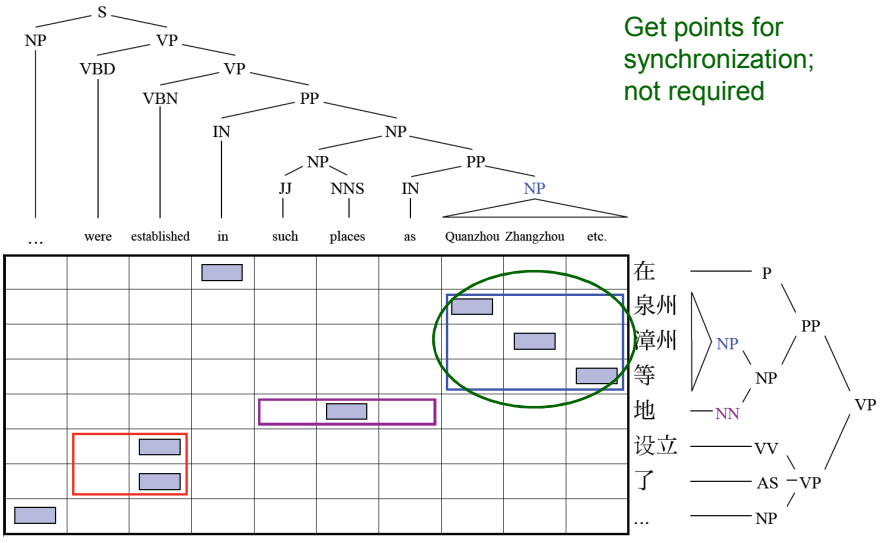


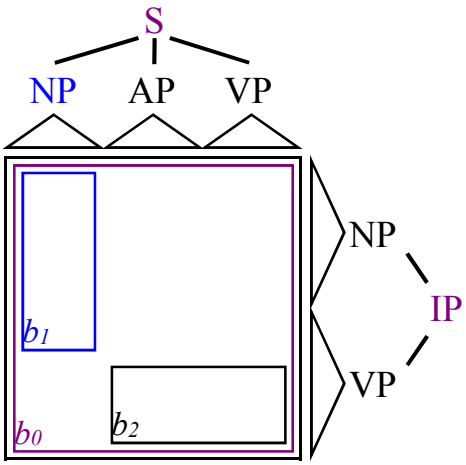

Separate PCFGs

# Adding Syntax: Weak Synchronization




Get points for synchronization; not required

# Weakly Synchronous Features




Parsing

$\phi_{\mathcal{F}}(\text{IP}, s)$
$\phi_{\mathcal{F}}(\text{NP}, s)$
$\phi_{\mathcal{F}}(\text{VP}, s)$

$\phi_{\mathcal{E}}(\text{S}, s')$
$\phi_{\mathcal{E}}(\text{NP}, s')$
$\phi_{\mathcal{E}}(\text{AP}, s')$
$\phi_{\mathcal{E}}(\text{VP}, s')$

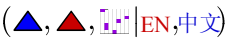
Alignment

$\phi_{\mathcal{A}}(b_0, s, s')$
$\phi_{\mathcal{A}}(b_1, s, s')$
$\phi_{\mathcal{A}}(b_2, s, s')$

Agreement

$\phi_{\triangleright}(\text{IP}, b_0)$
$\phi_{\triangleleft}(b_0, \text{S})$
$\phi_{\triangleleft}(b_1, \text{NP})$
$\phi_{\bowtie}(\text{IP}, b_0, \text{S})$

# Weakly Synchronous Model

$p_\theta$ (  |EN,中文)

Feature Type 1: Word Alignment

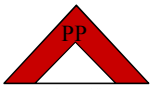
$\phi$(  , EN , 中文)

办公室

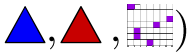
office [HBDK09]

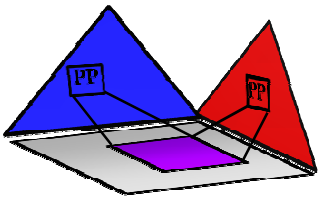
Feature Type 2: Monolingual Parser

$\phi$(  , EN )




Feature Type 3: Agreement

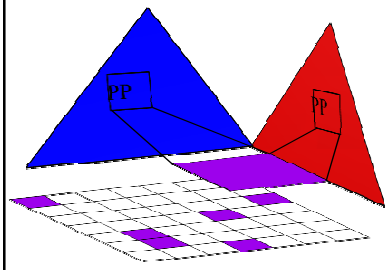
$\phi$(  )



# Inference: Structured Mean Field

- Problem: Summing over weakly aligned hypotheses is intractable
- Factored approximation: $p_\theta(\blacktriangle, \blacktriangle, \blacksquare \mid \text{EN}, \text{中文}) \approx q(\blacktriangle)q(\blacktriangle)q(\blacksquare)$
- Set $q$ to minimize $KL(\ q(\blacktriangle)q(\blacktriangle)q(\blacksquare),\ \ p_\theta(\blacktriangle, \blacktriangle, \blacksquare \mid \text{EN}, \text{中文})\ )$

## Algorithm

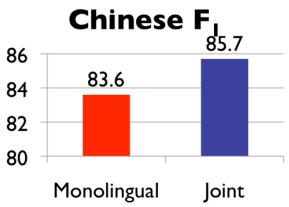


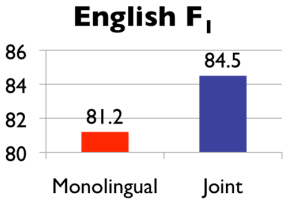

1) Initialize: $q(\blacktriangle)\ q(\blacktriangle)\ q(\blacksquare)$

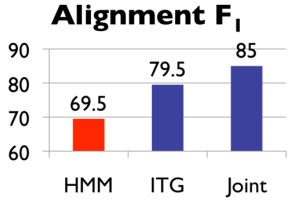
2) Iterate:

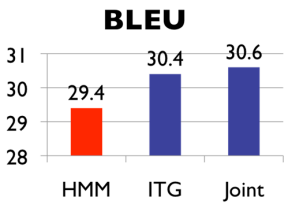
$$q(\blacktriangle) \propto \exp\{\langle\theta, \phi(\blacktriangle, E_q(\blacktriangle), E_q(\blacksquare))\rangle\}$$
$$q(\blacktriangle) \propto \exp\{\langle\theta, \phi(E_q(\blacktriangle), \blacktriangle, E_q(\blacksquare))\rangle\}$$
$$q(\blacksquare) \propto \exp\{\langle\theta, \phi(E_q(\blacktriangle), E_q(\blacktriangle), \blacksquare)\rangle\}$$

# Results



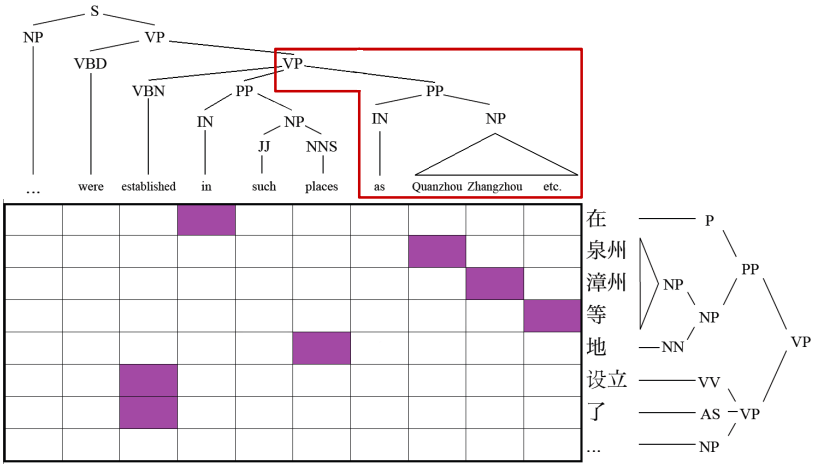



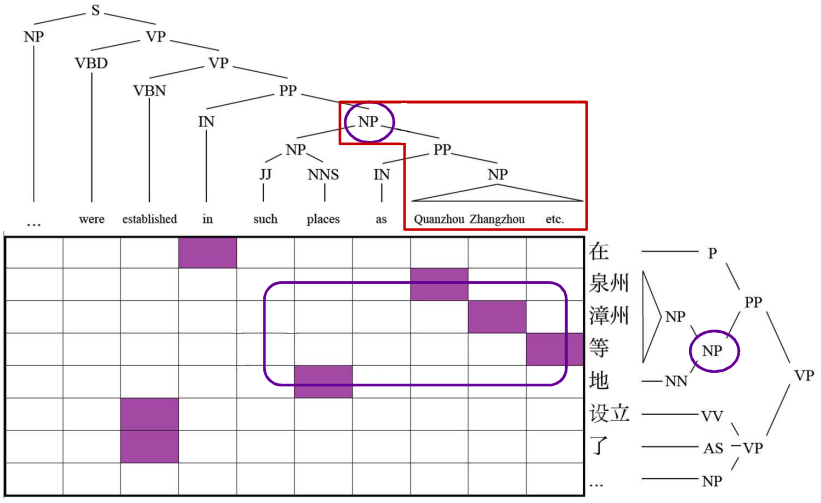




[Burkett, Blitzer, and Klein, NAACL 10]

# Incorrect English PP Attachment




# Corrected English PP Attachment



# Improved Translations

| 目前 | 导致 | 飞机 | 相撞 | 的 | 原因 | 尚 | 不 | 清楚, | 当地 | 民航 | 部门 | 将 | 对此 | 展开 | 调查 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cur-rently | cause | plane | crash | DE | reason | yet | not | clear, | local | civil aero-nautics | bureau | will | toward | open | investi-gations |

Reference

At this point the cause of the plane collision is still unclear. The local caa will launch an investigation into this .

Baseline (GIZA++)

The cause of planes is still not clear yet, local civil aviation department will investigate this .

Bilingual Adaptation Model

The cause of plane collision remained unclear, local civil aviation departments will launch an investigation .