The IIT Bombay Hindi⇔English Translation System at WMT 2014

Piyush Dungarwal, Rajen Chatterjee, Abhijit Mishra, Anoop Kunchukuttan, Ritesh Shah, Pushpak Bhattacharyya
Department of Computer Science and Engineering
Indian Institute of Technology, Bombay
{piyushdd,rajen,abhijitmishra,anoopk,ritesh,pb}@cse.iitb.ac.in

Abstract
In this paper, we describe our English-Hindi and Hindi-English statistical systems submitted to the WMT14 shared task. The core components of our translation systems are phrase based (Hindi-English) and factored (English-Hindi) SMT systems. We show that the use of number, case and Tree Adjoining Grammar information as factors helps to improve English-Hindi translation, primarily by generating morphological inflections correctly. We show improvements to the translation systems using pre-processing and post-processing components. To overcome the structural divergence between English and Hindi, we reorder the source side sentence to conform to the target language word order. Since parallel corpus is limited, many words are not translated. We translate out-of-vocabulary words and transliterate named entities in a post-processing stage. We also investigate ranking of translations from multiple systems to select the best translation.

1 Introduction
India is a multilingual country with Hindi being the most widely spoken language. Hindi and English act as link languages across the country and languages of official communication for the Union Government. Thus, the importance of English⇔Hindi translation is obvious. Over the last decade, several rule based (Sinha, 1995), interlingua based (Dave et. al., 2001) and statistical methods (Ramanathan et. al., 2008) have been explored for English-Hindi translation.

In the WMT 2014 shared task, we undertake the challenge of improving translation between the English and Hindi language pair using Statistical Machine Translation (SMT) techniques. The WMT 2014 shared task has provided a standardized test set to evaluate multiple approaches and avails the largest publicly downloadable English-Hindi parallel corpus. Using these resources, we have developed a phrase-based and a factored based system for Hindi-English and English-Hindi translation respectively, with pre-processing and post-processing components to handle structural divergence and morphological richness of Hindi. Section 2 describes the issues in Hindi⇔English translation.

The rest of the paper is organized as follows. Section 3 describes corpus preparation and experimental setup. Section 4 and Section 5 describe our English-Hindi and Hindi-English translation systems respectively. Section 6 describes the post-processing operations on the output from the core translation system for handling OOV and named entities, and for reranking outputs from multiple systems. Section 7 mentions the details regarding our systems submitted to WMT shared task. Section 8 concludes the paper.

2 Problems in Hindi⇔English Translation
Languages can be differentiated in terms of structural divergences and morphological manifestations. English is structurally classified as a Subject-Verb-Object (SVO) language with a poor morphology whereas Hindi is a morphologically rich, Subject-Object-Verb (SOV) language. Largely, these divergences are responsible for the difficulties in translation using a phrase based/factored model, which we summarize in this section.

2.1 English-to-Hindi
The fundamental structural differences described earlier result in large distance verb and modifier movements across English-Hindi. Local reordering models prove to be inadequate to over-
come the problem; hence, we transformed the source side sentence using pre-ordering rules to conform to the target word order. Availability of robust parsers for English makes this approach for English-Hindi translation effective.

As far as morphology is concerned, Hindi is more richer in terms of case-markers, inflection-rich surface forms including verb forms etc. Hindi exhibits gender agreement and syncretism in inflections, which are not observed in English. We attempt to enrich the source side English corpus with linguistic factors in order to overcome the morphological disparity.

2.2 Hindi-to-English

The lack of accurate linguistic parsers makes it difficult to overcome the structural divergence using preordering rules. In order to preorder Hindi sentences, we build rules using shallow parsing information. The source side reordering helps to reduce the decoder’s search complexity and learn better phrase tables. Some of the other challenges in generation of English output are: (1) generation of articles, which Hindi lacks, (2) heavy overloading of English prepositions, making it difficult to predict them.

3 Experimental Setup

We process the corpus through appropriate filters for normalization and then create a train-test split.

3.1 English Corpus Normalization

To begin with, the English data was tokenized using the Stanford tokenizer (Klein and Manning, 2003) and then true-cased using truecase.perl provided in MOSES toolkit.

3.2 Hindi Corpus Normalization

For Hindi data, we first normalize the corpus using NLP Indic Library (Kunchukuttan et. al., 2014). Normalization is followed by tokenization, wherein we make use of the trivtokenizer.pl provided with WMT14 shared task. In Table 1, we highlight some of the post normalization statistics for en-hi parallel corpora.

|                | English | Hindi |
|----------------|---------|-------|
| Token          | 2,898,810 | 3,092,555 |
| Types          | 95,551  | 118,285 |
| Total Characters | 18,513,761 | 17,961,357 |
| Total sentences | 289,832  | 289,832 |
| Sentences (word count ≤ 10) | 188,993  | 182,777 |
| Sentences (word count > 10) | 100,839  | 107,055 |

Table 1: en-hi corpora statistics, post normalization.

3.3 Data Split

Before splitting the data, we first randomize the parallel corpus. We filter out English sentences longer than 50 words along with their parallel Hindi translations. After filtering, we select 5000 sentences which are 10 to 20 words long as the test data, while remaining 284,832 sentences are used for training.

4 English-to-Hindi (en-hi) translation

We use the MOSES toolkit (Koehn et. al., 2007a) for carrying out various experiments. Starting with Phrase Based Statistical Machine Translation (PB-SMT)(Koehn et. al., 2003) as baseline system we go ahead with pre-order PBSMT described in Section 4.1. After pre-ordering, we train a Factor Based SMT(Koehn, 2007b) model, where we add factors on the pre-ordered source corpus. In Factor Based SMT we have two variations- (a) using Supertag as factor described in Section 4.2 and (b) using number, case as factors described in Section 4.3.

4.1 Pre-ordering source corpus

Research has shown that pre-ordering source language to conform to target language word order significantly improves translation quality (Collins et. al. 2005). There are many variations of pre-ordering systems primarily emerging from either rule based or statistical methods. We use rule based pre-ordering approach developed by (Patel et. al., 2013), which uses the Stanford parser (Klein and Manning, 2003) for parsing English sentences. This approach is an extension to an earlier approach developed by (Ramanathan et. al., 2008). The existing source reordering system requires the input text to contain only surface form, however, we extended it to support surface form...
along with its factors like POS, lemma etc.. An example of improvement in translation after pre-ordering is shown below:

**Example:** trying to replace bad ideas with good ideas.

**Phr:** replace **bure vichaaron ko acche vichaaron ke saath**

(\begin{align*}
\text{Gloss:} & \text{ replace bad ideas good ideas with}\n\end{align*})

**4.2 Supertag as Factor**

The notion of Supertag was first proposed by Joshi and Srinivas (1994). Supertags are elementary trees of Lexicalized Tree Adjoining Grammar (LTAG) (Joshi and Schabes, 1991). They provide syntactic as well as dependency information at the word level by imposing complex constraints in a local context. These elementary trees are combined in some manner to form a parse tree, due to which, supertagging is also known as “An approach to almost parsing” (Bangalore and Joshi, 1999). A supertag can also be viewed as fragments of parse trees associated with each lexical item. Figure 1 shows an example of supertagged sentence “The purchase price includes taxes” described in (Hassan et al., 2007). It clearly shows the sub-categorization information available in the verb include, which takes subject NP to its left and an object NP to its right.

![Supertag Example](image)

**Figure 1: LTAG supertag sequence obtained using MICA Parser.**

Use of supertags as factors has already been studied by Hassan (2007) in context of Arabic-English SMT. They use supertag language model along with supertagged English corpus. Ours is the first study in using supertag as factor for English-to-Hindi translation on a pre-ordered source corpus.

We use MICA Parser (Bangalore et. al., 2009) for obtaining supertags. After supertagging we run pre-ordering system preserving the supertags in it. For translation, we create mapping from source-word|supertag to target-word. An example of improvement in translation by using supertag as factor is shown below:

**Example:** trying to understand what your child is saying to you

**Phr:** आपका बच्चा आपसे का कह रहा है यह

(aapkaa bacchaa aapse kya kaha rahaa hai yaha)

**Gloss:** your child you what saying is this

**Supertag Fact:** आपका बच्चा आपसे का कह रहा है ,

उसे समझने की कोशिश करना

(aapkaa bacchaa aapse kya kaha rahaa hai, use samajhane kii koshish karna)

**Gloss:** your child to you what saying is , that understand try

**4.3 Number, Case as Factor**

In this section, we discuss how to generate correct noun inflections while translating from English to Hindi. There has been previous work done in order to solve the problem of data sparsity due to complex verb morphology for English to Hindi translation (Gandhe, 2011). Noun inflections in Hindi are affected by the number and case of the noun only. **Number** can be singular or plural, whereas, **case** can be direct or oblique. We use the factored SMT model to incorporate this linguistic information during training of the translation models. We attach root-word, number and case as factors to English nouns. On the other hand, to Hindi nouns we attach root-word and suffix as factors. We define the translation and generation step as follows:

- **Translation step (T0):** Translates English root|number|case to Hindi root|suffix

- **Generation step (G0):** Generates Hindi surface word from Hindi root|suffix

An example of improvement in translation by using number and case as factors is shown below:

**Example:** Two sets of statistics

**Phr:** दो के ऑक्कड़

(do ke aankade)

**Gloss:** two of statistics

**Num-Case Fact:** ऑक्कड़ के दो सेट

(aankadon ke do set)

**Gloss:** statistics of two sets
4.3.1 Generating number and case factors

With the help of syntactic and morphological tools, we extract the number and case of the English nouns as follows:

- **Number factor:** We use Stanford POS tagger\(^3\) to identify the English noun entities (Toutanova, 2003). The POS tagger itself differentiates between singular and plural nouns by using different tags.

- **Case factor:** It is difficult to find the direct/oblique case of the nouns as English nouns do not contain this information. Hence, to get the case information, we need to find out features of an English sentence that correspond to direct/oblique case of the parallel nouns in Hindi sentence. We use object of preposition, subject, direct object, tense as our features. These features are extracted using semantic relations provided by Stanford’s typed dependencies (Marneffe, 2008).

4.4 Results

Listed below are different statistical systems trained using Moses:

- Phrase Based model (*Phr*)
- Phrase Based model with pre-ordered source corpus (*PhrReord*)
- Factor Based Model with factors on pre-ordered source corpus
  - Supertag as factor (*PhrReord+STag*)
  - Number, Case as factor (*PhrReord+NC*)

We evaluated translation systems with BLEU and TER as shown in Table 2. Evaluation on the development set shows that factor based models achieve competitive scores as compared to the baseline system, whereas, evaluation on the WMT14 test set shows significant improvement in the performance of factor based models.

5 Hindi-to-English (hi-en) translation

As English follows SVO word order and Hindi follows SOV word order, simple distortion penalty in phrase-based models cannot handle the reordering well. For the shared task, we follow the approach that pre-orders the source sentence to conform to target word order.

A substantial volume of work has been done in the field of source-side reordering for machine translation. Most of the experiments are based on applying reordering rules at the nodes of the parse tree of the source sentence. These reordering rules can be automatically learnt (Genzel, 2010). But, many source languages do not have a good robust parser. Hence, instead we can use shallow parsing techniques to get chunks of words and then reorder them. Reordering rules can be learned automatically from chunked data (Zhang, 2007).

Hindi does not have a functional constituency or dependency parser available, as of now. But, a shallow parser\(^4\) is available for Hindi. Hence, we follow a chunk-based pre-ordering approach, wherein, we develop a set of rules to reorder the chunks in a source sentence. The following are the chunks tags generated by this shallow parser: Noun chunks (NP), Verb chunks (VGF, VGNF, VGNN), Adjectival chunks (JJP), Adverb chunks (RBP), Negatives (NEGP), Conjuncts (CCP), Chunk fragments (FRAGP), and miscellaneous entities (BLK) (Bharati, 2006).

5.1 Development of rules

After chunking an input sentence, we apply handcrafted reordering rules on these chunks. Following sections describe these rules. Note that we apply rules in the same order they are listed below.

5.1.1 Merging of chunks

After chunking, we merge the adjacent chunks, if they follow same order in target language.

1. Merge \{JJP VGF\} chunks (Consider this chunk as a single VGF chunk)
   
   e.g., वर्णित है (varnit hai), स्थित है (sthit hai)

\(^3\)http://nlp.stanford.edu/software/tagger.shtml

\(^4\)http://ltrc.iiit.ac.in/showfile.php?filename=downloads/shallow_parser.php

| Model             | Development BLEU | Development TER | WMT14 BLEU | WMT14 TER |
|-------------------|------------------|----------------|------------|-----------|
| *Phr*             | 27.62            | 0.63           | 8.0        | 0.84      |
| *PhrReord*        | 28.64            | 0.62           | 8.6        | 0.86      |
| *PhrReord+STag*   | 27.05            | 0.64           | 9.8        | 0.83      |
| *PhrReord+NC*     | 27.50            | 0.64           | 10.1       | 0.83      |

Table 2: English-to-Hindi automatic evaluation on development set and on WMT14 test set.
2. Merge adjacent verb chunks (Consider this chunk as a single verb chunk)  
   e.g., गिरता है (girataa hai), लूभाता है (lubhaataa hai)

3. Merge NP and JJP chunks separated by commas and CCP (Consider this chunk as a single NP chunk)  
   e.g., बड़ा और अहम (badaa aur aham)

5.1.2 Preposition chunk reordering

Next we find sequence of contiguous chunks separated by prepositions (Can end in verb chunks).  
We apply following reordering rules on these contiguous chunks:

1. Reorder multi-word preposition locally by reversing the order of words in that chunk  
   e.g., के अलावा (ke alaawaa) → अलावा के,  
   के सामने (ke saamanee) → सामने के  

2. Reorder contiguous preposition chunk by reversing the order of chunks (Consider this chunk as a single noun chunk)  
   e.g., हिंदु धर्म में तीर्थ का बड़ा महत्व (hinduu dharma me tirtha ka badaa mahatva) → बड़ा महत्व का तीर्थ में हिंदु धर्म

5.1.3 Verb chunk reordering

We find contiguous verb chunks and apply following reordering rules:

1. Reorder chunks locally by reversing the order of the chunks  
   e.g., वर्नित है (varnit hai) → है वर्नित  

2. Verb chunk placement: We place the new verb chunk after first NP chunk.  
   Same rule applies for all verb chunks in a sentence, i.e., we place each verb chunk after first NP chunk of the clause to which the verb belongs.

   Note that, even though placing verb chunk after first NP chunk may be wrong reordering.  
   But we also use distortion window of 6 to 20 while using phrase-based model.  
   Hence, further reordering of verb chunks can be somewhat handled by phrase-based model itself.

   Thus, using chunker and reordering rules, we get a source-reordered Hindi sentence.

5.2 Results

We trained two different translation models:

- Phrase-based model without source reordering (Phr)
- Phrase-based model with chunk-based source reordering (PhrReord)

| Model      | Development BLEU | Development TER | WMT14 BLEU | WMT14 TER |
|------------|------------------|------------------|------------|-----------|
| Phr        | 27.53            | 0.59             | 13.5       | 0.87      |
| PhrReord   | 25.06            | 0.62             | 13.7       | 0.90      |

Table 3 shows evaluation scores for development set and on WMT14 test set.

Table 3 shows evaluation scores for development set and WMT14 test set. Even though we do not see significant improvement in automatic evaluation of PhrReord, but this model contributes in improving translation quality after ranking, as discussed in Section 5.  
In subjective evaluation we found many translation to be better in PhrReord model as shown in the following examples:

**Example 1:** सन 2004 से वे कई बार चोटियों में रहे हैं | (sana 2004 se ve kaii baar chotiiyon me rhie hain.)  
Phr: since 2004 he is injured sometimes  
PhrReord: he was injured many times since 2004

**Example 2:** ओबामा का राष्ट्रपति पद के चुनाव प्रचार हेतु बनाया आधिकारिक जालस्थल  
( obama ka rashtrapti pad ke chunaav prachaar hetu banaayaa aadhikaarik jalsalal )  
Phr: of Obama for election campaign  
PhrReord: official website of Obama created for  
President campaign

6 Post processing

All experimental results reported in this paper are after post processing the translation output. In post processing, we remove some Out-of-Vocabulary (OOV) words as described in subsection 6.1, after which we transliterate the remaining OOV words.

6.1 Removing OOV

We noticed, there are many words in the training corpus which were not present in the phrase table, but, were present in the lexical translation table.  
So we used the lexical table as a dictionary to lookup bilingual translations.  
Table 4 gives the statistics of number of OOV reduced.
### Table 4: Statistics showing number of OOV before and after post processing the English-to-Hindi translation output of Development set.

| Model                      | Before | After |
|----------------------------|--------|-------|
| Phrased Based              | 2313   | 1354  |
| Phrase Based (pre-order)   | 2256   | 1334  |
| Supertag as factor         | 4361   | 1611  |
| Num-Case as factor         | 2628   | 1341  |

6.2 Transliteration of Untranslated Words

OOV words which were not present in the lexical translation table were then transliterated using a naive transliteration system. The transliteration step was applied on Hindi-to-English translation outputs only. After transliteration we noticed fractional improvements in BLEU score varying from 0.1 to 0.5.

6.3 Ranking of Ensemble MT Output

We propose a ranking framework to select the best translation output from an ensemble of multiple MT systems. In order to exploit the strength of each system, we augment the translation pipeline with a ranking module as a post processing step. For English-to-Hindi ranking we combine the output of both factor based models, whereas, for Hindi-to-English ranking we combine phrase based and phrase based with pre-ordering outputs.

For most of the systems, the output translations are adequate but not fluent enough. So, based on their fluency scores, we decided to rank the candidate translations. Fluency is well quantified by LM log probability score and Perplexity. For a given translation, we compute these scores by querying the 5-gram language model built using SRILM. Table 5 shows more than 4% relative improvement in BLEU score for en-hi as well as hi-en translation system after applying ranking module.

### Table 5: Comparision of ranking score with baseline.

| Model                  | BLEU  | METEOR | TER  |
|------------------------|-------|--------|------|
| Phr(en-hi)             | 27.62 | 0.41   | 0.63 |
| After Ranking (en-hi)  | 28.82 | 0.42   | 0.63 |
| Phr(hi-en)             | 27.53 | 0.27   | 0.59 |
| After Ranking (hi-en)  | 28.69 | 0.27   | 0.59 |

7 Primary Systems in WMT14

For English-to-Hindi, we submitted the ranked output of factored models trained on pre-ordered source corpus. For Hindi-to-English, we submitted the ranked output of phrase based and pre-ordered phrase based models. Table 6 shows evaluation scores of these systems on WMT14 test set.

### Table 6: WMT14 evaluation for en-hi and hi-en.

| Lang. pair | BLEU | TER  |
|------------|------|------|
| en-hi      | 10.4 | 0.83 |
| hi-en      | 14.5 | 0.89 |

8 Conclusion

We conclude that the difficulties in English-Hindi MT can be tackled by the use of factor based SMT and various pre-processing and post processing techniques. Following are our primary contributions towards English-Hindi machine translation:

- Use of supertag factors for better translation of structurally complex sentences
- Use of number-case factors for accurately generating noun inflections in Hindi
- Use of shallow parsing for pre-ordering Hindi source corpus

We also observed that simple ranking strategy benefits in getting the best translation from an ensemble of translation systems.

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