Translational Equivalence and Cross-lingual Parallelism: The Case of FrameNet Frames

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Abstract

Annotation projection is a strategy for the cross-lingual transfer of annotations which can be used to bootstrap linguistic resources for low-density languages, such as role-semantic databases similar to FrameNet.

In this paper, we investigate the main assumption underlying annotation projection, *cross-lingual parallelism*, which states that annotation is parallel across languages. Concentrating on the level of *frames*, we provide a qualitative and quantitative characterisation of the relationship between translation and cross-lingual parallelism on the basis of a trilingual English–French–German corpus. We link frame (non)-parallelism to different kinds of *translational shifts* and show that a simple heuristic can detect the majority of such shifts.

1 Introduction

Recent work in computational linguistics suggests that many applications could benefit from a representation of text on the level of *predicate-argument structure* which abstracts away from idiosyncrasies of the text's surface structure. A promising descriptive framework for predicate-argument structure is provided by theories of *semantic roles* such as Frame Semantics (1985), and semantic role representations have been shown to be beneficial for a number of tasks ranging from question answering (Narayanan and Harabagiu, 2004) and the representation of propositional information in biomedicine (Cohen and Hunter, 2006) to cognitive tasks like modelling human sentence processing (Padó et al., 2006).

A crucial prerequisite for the use of semantic roles in NLP is the availability of robust and accurate models for the assignment of frames and roles to free text, a task often called *shallow semantic parsing*. Starting with the seminal study by Gildea and Jurafsky (2002), much effort has been spent on developing data-driven models for this task. Unfortunately, state-of-the-art shallow semantic parsing techniques still rely heavily on large annotated corpora. While such a resource is available for English in the form of the FrameNet database (Fillmore et al., 2003), the high cost of manual semantic annotation (Burchardt et al., 2006) has impeded the development of comparable resources for almost all other languages.

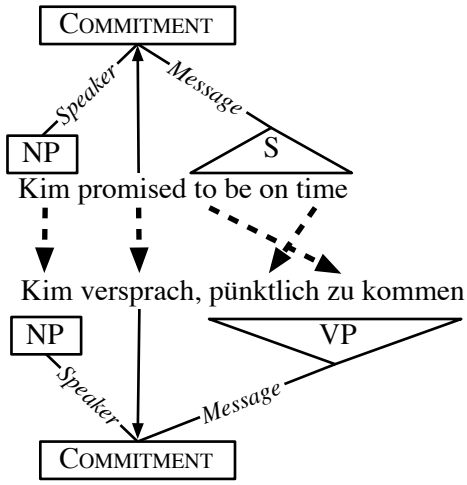

Figure 1: Annotation projection of frame-semantic annotation from English onto German.

An elegant solution to this resource scarcity problem is *annotation projection* (Yarowsky et al., 2001), a technique which uses parallel corpora to automatically transfer linguistic annotations from a source language onto a target language by following *translational equivalence links* in parallel sentence pairs (bisentences). Figure 1 illustrates this idea for frame-semantic annotation. We assume that the English side has been analysed – here, the verb *promise* introduces the frame COMMITMENT with the roles *Speaker* (assigned to the NP *Kim*) and *Message* (assigned to the

sentence *to be on time*). Annotation can now simply follow translational equivalence links (shown as dashed lines) to induce corresponding frame and role annotation for the German sentence: the frame COMMITMENT is now introduced by *versprach*, and its roles point to *Kim* (*Speaker*) and *pünktlich zu kommen* (*Message*), respectively. Thus, the manual work spent on the development of existing resources can be reused to create corresponding resources for other languages. Projection has been applied to the English FrameNet to induce corresponding resources for a number of languages, such as French (Padó and Pitel, 2007), German (Padó and Lapata, 2005b; Padó and Lapata, 2006), Spanish (Johansson and Nugues, 2005), and Swedish (Johansson and Nugues, 2006).

What must be kept in mind, however, is that the success of annotation projection relies on *cross-lingual parallelism*: The strategy proceeds by *copying* annotation directly across languages. When the translation does not preserve the linguistic analysis of the source sentence, projection is thus bound to assign an erroneous analysis to the target sentence.

At first glance, the parallelism assumption appears to be particularly problematic for frame-semantic analyses, since these consist of two levels, namely the frame assigned to the predicate and the realised roles. Due to the design of FrameNet, which defines semantic roles at the level of frames, roles can only be projected successfully if the frame is parallel. If a different frame is evoked by the target predicate, there is no guarantee that the projected roles are interpretable. It is therefore important to investigate the actual degree of frame and role parallelism in parallel corpora for different language pairs, to gauge the degree to which the parallelism assumption is warranted. Unfortunately, the studies listed above have concentrated on role parallelism, and either simply assumed frame parallelism, or limited their evaluation to cases of frame parallelism.

This paper addresses the question of cross-lingual parallelism on the *frame* level by providing a detailed, data-driven investigation. We base our discussion on the corpus of 1000 English–German bisentences with manual frame-semantic annotation described in Padó and Lapata (2005b).[1] We recently extended this corpus with a third language, by tagging the French translations of all original bi-sentences (Padó and Pitel, 2007). We re-used the original annotation guidelines, which allows us to verify our conclusions on two language pairs exemplifying different language families. In addition, the English–French bitext is not affected by possible biases introduced by the informed sampling strategy used for the creation of the English–German bitext.

[1] The corpus is available for download from `http://www.coli.uni-saarland.de/~pado/data.html`.

Plan of the paper. We proceed in three stages: In Section 2, we make the notion of cross-lingual parallelism more precise and investigate the scale of the problem. Section 3 then characterises the processes underlying frame non-parallelism using concepts from translation science. Finally, in Section 4, we sketch how the results motivate a simple heuristic to automatically detect affected instances.

2 Cross-lingual interpretability and parallelism

This Section provides a discussion of *cross-lingual parallelism*, the assumption that "translation preserves linguistic annotation". We introduced this assumption in Section 1 as essential for successful annotation projection, but have yet to develop a better understanding of it. Arguably, cross-lingual parallelism involves two steps, which we inspect in turn. First, it assumes that a linguistic theory for language A can be used "as is" for the analysis of language B (*cross-lingual interpretability*). Second, it assumes that the concrete translation process within each bisentence preserves the linguistic analysis of the source sentence (*cross-lingual parallelism* proper).

Cross-lingual interpretability. Cross-lingual interpretability is a claim about a linguistic theory T. It states that the *descriptive inventory* of T that is used to analyse some source language can be also used to analyse the target language in question.

While many early formal theories in linguistics (such as Chomsky's universal grammar or Katz and Fodor's theory of semantics) were aimed at perfect cross-lingual interpretability, this turned out to be infeasible in practice. However, these studies also yielded insights about properties of theories that lend themselves at least to high degrees of interpretability. One crucial factor is *granularity of description*: The

coarser the categories, the more likely they can be observed (and thus interpreted) cross-linguistically.[2]

Judging on these grounds, FrameNet frames can be expected to stand a good chance of cross-lingual interpretability. They can be seen as coarse-grained semantic classes of predicates which are *conceptually similar* by virtue of referring to schematised situations which can be expected to to apply across languages to a high degree (see also Boas (2005)). The cross-lingual interpretability of frames is limited by another factor, though. In addition to conceptual similarity, membership of a predicate in a frame has to be grounded *linguistically* by the predicate's syntactic ability to realise the frame's semantic roles. Thus, frames may not be interpretable in languages where the subcategorisation of predicates differs substantially from their English translations.

These expectations are borne out well by actual experiences from projects which directly re-use FrameNet frames for the semantic annotation of other languages (Subirats and Petruck, 2003; Ohara et al., 2004; Burchardt et al., 2006). Since cross-lingual interpretability is difficult to quantify, the evidence is qualitative in nature; however, several general tendencies have become apparent: (a), for any given language, a substantial majority of FrameNet frames is directly applicable; (b), the degree of interpretability is inversely related to the typological distance from English; (c), some semantic domains may be particularly problematic.

Cross-lingual parallelism. Even if a linguistic theory exhibits perfect cross-lingual interpretability, it can be completely unsuitable for annotation projection. The reason is that cross-lingual interpretability is not concerned at all with the analysis of *concrete utterances*. This point can be illustrated on the syntactic analysis of Figure 1, where we find that the syntactic category of the English phrase "to be on time" (sentence) diverges from the category of its German translation "pünktlich zu kommen" (verb phrase). Even though we can safely assume that the categories VP and S are interpretable in both languages, simple annotation projection would result in a wrong syntactic analysis for the German phrase.

[2]Naturally, this involves a trade-off: By concentrating on cross-lingual generalisations, the description provided by coarse-grained categories is, by definition, incomplete.

Language	Measure	Precision	Recall	F-score
EN→DE	FrameParal	0.72	0.72	0.72
	RoleParal	0.91	0.92	0.91
EN→FR	FrameParal	0.65	0.74	0.69
	RoleParal	0.88	0.87	0.88

Table 1: Cross-lingual parallelism of frame-semantic annotation on the frame and role levels

Thus, provided that interpretability is not an issue, the key question for the applicability of annotation projection is the degree of *cross-lingual parallelism* proper. We define cross-lingual parallelism to hold if a linguistic unit and its *translational equivalent* in a parallel corpus receive identical analyses.

The question of cross-lingual parallelism has been investigated by a number of studies for different levels of linguistic analysis, revealing an interesting trend: it appears that syntactic annotation, such as NP bracketings (Yarowsky et al., 2001) or dependency relations (Hwa et al., 2005) show only a quite low degree of cross-lingual parallelism (e.g., <40% for dependency relations).[3] In contrast, studies on lexical-semantic annotation in the widest sense, such as word sense (Bentivogli and Pianta, 2005) or coreference (Postolache et al., 2006), show a substantially higher degree of parallelism, often in excess of 80%.

These results give reason to hope that Frame Semantics, as an instance of lexical-semantic annotation, also shows a high degree of cross-lingual parallelism. To validate this hypothesis, we have analysed the corpus described in Section 1. The results are shown in Table 1. "FrameParal" measures how many frames simultaneously in both halves of a bisentence, and "RoleParal" measures the same number for semantic roles of parallel frames. To compute precision and recall, we treat the annotations of the target language (i.e., German and French) as gold standard against which we compare the English annotations. Since all major tendencies hold across both target languages, we discuss them jointly.

We first observe that provided that the frames are parallel, the roles are show a very high degree of parallelism (above 90%). This lends strong support to the amenability of semantic roles to annotation projection, and accounts for the favourable role projection results found by the studies listed in Section 1.

[3]Annotation projection for syntax therefore often employs post-projection rewriting steps to modify the source annotation.

Given our discussion above, however, this finding is not overly surprising, since due to the design principles of FrameNet, instances of frame parallelism draw from the same set of semantic roles. In fact, a more detailed analysis of the mismatch cases shows that most of the mismatches are cases of argument elision in one of the languages (e.g., passives).

It thus appears that the crucial factor in determining the prospects of annotation projection is in fact the degree of frame parallelism. Our data show that the situation is not as clear-cut as for role parallelism: The degree of frame parallelism is substantially lower, ranging around 70%. On the one hand, this number indicates that a majority of frame instances is preserved in translation, particularly taking into account that the *monolingual* inter-annotator agreement for frames on our dataset was not 100%, but 87%. On the other hand, it shows that there is a substantial fraction of instances of translated predicates where the frame changes, and thus annotation projection should not be applied.

3 Characterising Frame (Non)-Parallelism

In the last section, we have established that frame non-parallelism is in fact a substantial phenomenon. This section aims at characterising the circumstances of frame non-parallelism in parallel corpora.

3.1 Frame Parallelism and Translational Shifts

Recall from Section 2.2 that cross-lingual parallelism considers the relationship between the analyses of translationally equivalent linguistic units. Thus, a promising source for insight about cross-lingual parallelism is translation science. This field has known for a long time that *"translations deviate in many ways from their originals"* (Cyrus, 2006), and has investigated the linguistic changes arising from translation, termed *translational shifts* (Catford, 1965).

Cyrus' (2006) recent classification of translational shifts is particularly interesting for our study, since it is aimed specifically at investigating the relationship between predicates (and arguments) and their translations. It distinguishes two main classes of translational shifts. The first is *grammatical shifts*, such as change of voice, category change, or (de-) pronominalisation. The second consists of *semantic shifts*, the two most important of which are *modification* and *mutation*.[4] Modification is defined as "some type of semantic divergence, for example a difference in aktionsart", where the lexical meaning of the two predicates is still comparable. Modification has two subclasses, namely *explicitation* and *generalisation*, where more specific (or less specific) predicates are chosen as translations. The other class, mutation, covers cases of translation where the words "differ radically in their lexical meaning".

This classification throws some new light onto the difference between syntactic and lexico-semantic annotation observed in Section 2. Presumably, syntactic annotation is sensitive to grammatical shifts in translation, and by extension to semantic shifts which are often accompanied by grammatical shifts. In contrast, lexico-semantic annotation tends to abstract over grammatical properties, and thus can exhibit a higher degree of cross-lingual parallelism.

Figure 2 illustrates the case of FrameNet as a type of lexico-semantic annotation. In the figure, the translation process is modelled as consisting of an interpretation step, which recovers an underlying state of affairs from a source language expression, and a generation step, which re-expresses this state of affairs in a new language. This leads to an upside-down version of the well-known Vauquois triangle (Vauquois, 1975), where frames can be seen as an intermediate, partly language-independent layer.

The graph on the left shows the case of grammatical shifts. These do not involve a change in the frame, since all possible reformulations of a state of affairs which involve only a grammatical shift share a common frame. Even category change is unproblematic, since frames can be evoked by predicates of different parts of speech. For example, the frame COMMITMENT can be evoked by the verbs *promise, vow, pledge* as well as by the nouns *promise, oath*, and others. In contrast, the graph on the right displays the typical case of semantic shifts: when the translator decides to express the state of affairs in the target language with an expression that deviates considerably from the source expression, frame non-parallelism may arise. Note, though, that due to the fairly coarse granularity of frame-semantic classes, not every semantic shift results in frame non-parallelism. We will

[4] Cyrus lists two additional semantic shifts, namely addition and deletion, which we disregard since we only consider the case where two corresponding predicates exist.

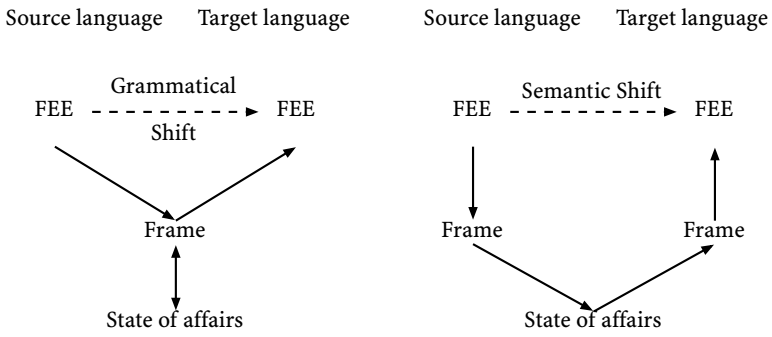

Figure 2: The connection between translation and frame parallelism (left) and frame non-parallelism (right)

discuss this point in detail in the next section.

3.2 Which Semantic Shifts Break Frame Parallelism?

In this section, we investigate what types of semantic shifts lead to frame non-parallelism. Optimally, such a study would be grounded in an small, but exhaustive, inventory of generic semantic shifts. Unfortunately, it seems that such an inventory is difficult to develop. Cyrus herself does not further subdivide her classes, noting that "it is rather difficult to find objective criteria" to distinguish even for the shifts she describes. The same issue has come up in the equivalent monolingual task of characterising the semantic relation between paraphrases in linguistic terms. For example, Barzilay and McKeown (2001) found that existing resources like WordNet have an insufficient inventory of relations and that "non-classical" relations are necessary. While a number of such relations have been investigated in the context of relation extraction over the last years, we are not aware of any successful efforts to construct a complete set of generic, "non-classical" semantic relations.

In the absence of such a resource, we use Cyrus' binary modification/mutation distinction as a basis, and provide an overview of the phenomena for which we find support in our corpus. While this method is clearly not exhaustive, it should provide an interesting insight into the types of semantic shifts that occur. For convenience, we always describe translation as taking place from English into another language.

Modification. Recall that modification assumes that lexical meaning is preserved to a large extent. Thus, frames can be parallel for "mild" cases of modification, while "serious" cases can result in non-parallelism. Modification is "mild" when the relation between the two predicates is one of synonymy, near-synonymy, or "mild" explicitation/generalisation. For example, both *say* and *wiederholen 'reiterate'* evoke the same frame, STATEMENT, even though *reiterate* is clearly an explicitation of *say*.

In contrast, a frequent phenomenon which leads to frame non-parallelism is translation that is sensitive to the predicates' arguments. For example, the predicates from the frame CAUSE_CHANGE_OF_SCALAR_POSITION, such as *increase* or *raise*, are used in English to very generally express processes of change. In contrast, French has a tendency to systematically use more specific frames, depending on the semantic type of the changing ITEM. Since FrameNet assumes that frame choice is determined lexically (by the predicate), frame non-parallelism can ensue, as in the following example:

(1) Extending the Community's legal competence within the framework of the third pillar has **increased** the burden.

Le fardeau s'est **alourdi** avec une extension de la compétence juridictionnelle communautaire dans le cadre du troisième pilier.

Here, the combination *increase [weight]* is translated with the more specific French *alourdir 'to make heavier'* which should presumably evoke the frame CAUSE_EXPANSION.

However, particularly in the case of explicitation/generalisation, the boundary to "serious" modification is hard to draw. Arguably, this mirrors a problem on the FrameNet side, namely the difficulty

to define in a precise manner the degree of *conceptual similarity* necessary for predicates to evoke the same frame, and to do so independently of the semantic domain (cf. Ellsworth et al. (2004)). In fact, it appears that the granularity of FrameNet frames is not completely uniform across all frames. In addition, there seems to be a tendency in FrameNet over time towards constructing more fine-grained frames which require a higher degree of conceptual similarity. This development is problematic from a cross-lingual point of view, since it leads to a higher number of instances with frame non-parallelism.

As a last prominent modification phenomenon, consider *change in aktionsart*, which is a clear-cut case of "serious" modification. In the following example, the causative English *raise* is translated by the inchoative French *monter 'rise'*:

(2) [. . .] The employment rate within the EU can be **raised** to 70%.

Le niveau d' emploi pourrait **monter** à 70% dans l' UE.

The resulting change in valency means that the English frame CAUSE_CHANGE_OF_SCALAR_POSITION cannot be evoked by the translation. Rather, *monter* evokes CHANGE_OF_SCALAR_POSITION.

As a final remark on modification, note that the frame non-parallelism introduced by this class of shifts is "benign" in that the semantic relation between original and translation almost always corresponds to a frame-to-frame relation in the FrameNet frame hierarchy. Examples are inheritance (for explicitation) or causative-of/inchoative-of (for change of aktionsart). When this hierarchy, which is still mostly exemplary, reaches a more complete state, it may be possible to treat all instances of modification as cases of (generalised) frame parallelism.

Mutation. Recall that in the case of mutation, the lexical meaning of the translation differs substantially from the original. Thus mutation, as a rule, results in frame non-parallelism. The right hand side of Figure 2 furthermore illustrates that mutation involves the usage of two different frames to describe the underlying state of affairs. The fact that this happens is not particularly surprising: Frames do not describe the complete meaning of the predicates they describe, but only its most salient meaning aspect. Since all but the most simple real-world states of affairs combine more than one meaning aspect, there are almost always "several ways of putting it", with different frames competing for the linguistic realisation.

The instances of mutation which we find in our corpus form a very inhomogeneous group, and are located along a continuum of *genericity*. On one end, we find cases which can be characterised well in terms of generic lexical relations such as causation, event–subevent, process–result, or perspectivisation. In this sense, they are similar to modification cases. However, translations further along the continuum become more and more idiosyncratic. The extreme is formed by instances whose interpretation involves a lot of world knowledge, and which are presumably very difficult to classify in terms of a general set of lexical relations.[5] The following examples illustrate different points on this continuum.

First, Example (3) shows an instance of a clear generic relation, where English expresses a process (*increase*), while French expresses the resulting end state (*atteindre 'reach'*):

(3) Why, for example, was the proposal to **increase** Europe's active population to 75% of the total population removed?

Pourquoi a-t-on retiré par exemple la proposition prévoyant que la population active devait **atteindre** 75% en Europe?

The relation between source and target expression becomes more elusive in the following example:

(4) The legal issue should take second place to consumer protection and **preventing** the public from harm.

La question juridique doit venir après la protection des consommateurs et les **précautions** pour nos citoyens.

What exactly is the relation between *prevent* and *précaution 'precaution'*? One possible interpretation is as a weaker version of process–result relation from above: since a precaution only *typically* implies that something is prevented, the relation might be characterised as process–typical result. However, this is not

[5] Arguably, metaphors form a prominent class of idiosyncratic mutations. They do not figure prominently in our study, through, since the guidelines asked our annotators to annotate "understood" rather than "literal" meanings.

the only possible characterisation: It is also possible to argue that a precaution is introduced *in order to* prevent something, and that the example is thus an instance of a means–purpose relation.

The last example illustrates the far end of the genericity continuum:

(5) Questions that were not **answered** during Question Time shall be answered in writing.

Les questions qui ne sont pas **examinées** pendant l' heure des questions recevront une réponse écrite.

The relation between *answer* and its translation *examiner 'examine'* can only be understood in the particular context of queries, where a response typically involves examining the issue at hand. This specificity makes it very hard to classify the translation pair *answer–examiner* in terms of generic relations.

4 Detecting Frame Non-Parallelism

We now come back to our original motivation, namely annotation projection of frame-semantic annotation. As we argued in Section 2, we need to detect instances of frame parallelism and non-parallelism to limit projection to parallel cases.

Our data analysis in Section 3, however, has left us with the impression that this distinction is difficult to make in a linguistically informed way. The inhomogeneity of the instances of non-parallelism combined with the difficulty of consistently delimiting FrameNet frames makes it difficult to relate this distinction in a straightforward manner to linguistic properties of the translation. We therefore propose to identify frame parallelism *distributionally* by observering properties of the translation and its context, a strategy which we have found to be effective for a related task, namely the cross-lingual induction of frame-semantic lexicons (Padó and Lapata, 2005a).

In this paper, we limit ourselves to outlining a naive heuristic on the type level, namely the *predominant sense heuristic* originally proposed for word sense disambiguation (McCarthy et al., 2004). This heuristic, which always assigns the most frequent (predominant) sense, is a serious rival for deeper methods, due to the skewed frequency of word senses. In our scenario, the predominant sense is the frame that is most often assigned to a predicate in the target language, and the heuristic consists in performing projection only if the source language frame is the predominant sense. Let t be a target predicate, s a source predicate, and f a frame. The decision rule is

$$\text{Project } f \text{ onto } t \text{ iff } \quad P(f|t) = \operatorname*{argmax}_f P(f|t)$$

where

$$P(f|t) = \frac{P(f,t)}{P(t)} = \frac{\sum_s P(f,t,s)}{\sum_f \sum_s P(f,t,s)}$$

We estimated the joint probabilities $P(f,t,s)$ from the complete EUROPARL corpus, using word alignments as indicators of translational equivalence, and testing two strategies for counting frames. The first was completely unsupervised and simply treated all frames listed in FrameNet for some source predicate s as seen for each instance of s (AllFrames). The second used a state-of-the-art frame disambiguation system (Erk, 2005) to assign the single most probable frame to each instance of s (BestFrame).

Language	Measure	Precision	Recall	F-score
EN→DE	Unfiltered	0.72	0.72	0.72
	AllFrames	0.89	0.51	0.65
	BestFrame	0.91	0.48	0.63
EN→FR	Unfiltered	0.65	0.74	0.69
	AllFrames	0.88	0.53	0.66
	BestFrame	0.90	0.49	0.63

Table 2: Impact of "predominant sense" filtering on cross-lingual frame parallelism

Table 1 shows the evaluation of these strategies on our 1000-sentence test corpus. The two language pairs again behave similarly. The results are encouraging: The predominant sense heuristic is able to detect the majority of instances of non-parallelism even without disambiguation (AllFrames), thus substantially improving precision. Frame disambiguation (BestFrame) reaps an additional small benefit, with final precision figures around 90%.

The practical applicability of this filtering scheme depends on the application, though. While the deterioration in recall that results from filtering (from 70% to around 50%) is presumably not a large problem, considering the size of parallel corpora available, predominant sense filtering results in a dataset for the target language where each target predicate is tagged with only one frame, namely the predominant one, and where all "minority readings" are discarded.

5 Conclusions

In this paper, we have discussed the question of cross-lingual parallelism of FrameNet frame instances in a parallel corpus. This problem is relevant in the context of using annotation projection to create frame-semantic resources for new languages. We have first discussed the concepts of cross-lingual interpretability and parallelism, and then characterised the cross-lingual parallelism of semantic frames quantitatively (in a parallel corpus) and qualitatively (in relation to translational shifts). Finally, we have sketched a strategy for identifying non-parallel instances.

We see two main avenues of future research. The first is a task-based evaluation of non-parallelism detection in the context of inducing shallow semantic parsers for the target language (Johansson and Nugues, 2006). The second is the replacement of the simplistic type-level "predominant sense" heuristic used in this paper by a token-level model of parallelism based on the lexical context. Such strategies work well in monolingual contexts (Erk, 2006) and have the potential of alleviating both the recall and the monosemy problem.

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