

Natural Language Ontology of Action. A gap with huge consequences for Natural Language Understanding and Machine Translation

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Abstract

Action verbs are the less predictable linguistic type for bilingual dictionaries and they cause major problems for MT technologies that are immediately evident to the user. This is not only because of language specific phraseology, but is rather a consequence of the peculiar way each natural language categorizes events i.e. it is a consequence of semantic factors. In ordinary languages the most frequent Action verbs are “general”, since they extend productively to actions belonging to different ontological types. Moreover, each language categorizes action in its own way and therefore the cross-linguistic reference to everyday activities is puzzling. But the ontology of actions is not available in any existing repository and our knowledge on the actual variation of verbs across action types is largely unknown. This paper briefly sketches the problem constituted by the Ontology of Action when disambiguation and cross-linguistic reference to action is concerned and presents the IMAGACT Ontology Infrastructure, which aims at filling this gap.

Keywords: LRL, Cross-linguistic Ontology, Action verbs, Disambiguation, Machine Translation, Open Language Infrastructure

1. The Semantic Variation of Action verbs within and across Languages

In all language modalities Action verbs bear the basic information that should be processed in order to make sense of a sentence. Especially in speech, they are the more frequent structuring elements (Moneglia and Panunzi, 2007), but no one to one correspondence can be established between action predicates in different languages, since the action types they refer to vary within and across languages (Majid et al., 2008).

For instance, the English instruction *to take* can lead to

qualitatively different actions, some of which are identified in Fig. 1. In model 1 the actor assumes the control of an object and changes its location; in 4 the actor receives the object; in 5 the actor takes the object away from somebody else, and so on. In short, in the above circumstances more than one single action type occurs.

This judgment is confirmed by the productivity of each action type. For instance, despite the fact that the predicate is applied to different objects, humans are able to judge that the same type of action is performed in all examples reported in each cell of Fig.1.






| | English | Italian | French | Spanish |
|----|--|---|--|---|
| 1. |  <ul style="list-style-type: none"> - take the glass - take the dishes - take the candle - take the coat | <ul style="list-style-type: none"> - prendere il bicchiere - prendere i piatti - prendere la candela - prendere il cappotto | <ul style="list-style-type: none"> - prendre le verre - prendre les plats - prendre la bougie - prendre le manteau | <ul style="list-style-type: none"> - coger el vaso - coger los platos - coger el candil - coger el abrigo |
| 2. |  <ul style="list-style-type: none"> - take the umbrella and leave - take the money and leave - take the foodstuffs for the journey - take the horse outside | <ul style="list-style-type: none"> - prendere l'ombrello per uscire - prendere gli spiccioli - prendere delle cose da mangiare per il viaggio - prendere il cavallo per partire | <ul style="list-style-type: none"> - prendre le parapluie pour sortir - prendre l'argent - prendre des choses à manger pour le voyage | <ul style="list-style-type: none"> - coger el paraguas al salir - coger el dinero - coger comida para el viaje - ccoger el caballo para salir |
| 3. |  <ul style="list-style-type: none"> - take the laptop out of the bag - take the liquid out of the bottle - take out the milk from the freezer to give to the mikman | <ul style="list-style-type: none"> - prendere il portatile dalla borsa - prendere il liquido dalla provetta - prendere il latte dal freezer per consegnarlo al lattai | <ul style="list-style-type: none"> - prendre l'ordinateur portable du sac - prendre le liquide de l'éprouvette - prendre le lait du réfrigérateur pour le consigner | <ul style="list-style-type: none"> - coger (sacar) el portatil de la funda - coger (sacar) el liquido de proveta - coger la leche del congelador para darsela al lechero |
| 4. |  <ul style="list-style-type: none"> - take the book from the assistant | <ul style="list-style-type: none"> - prendere il libro dall'assistente | <ul style="list-style-type: none"> - prendre (recevoir) le livre à l'assistant | <ul style="list-style-type: none"> - coger el libro del asistente |
| 5. |  <ul style="list-style-type: none"> - take the money from the girl - take the hat off the lady - take the food from the people | <ul style="list-style-type: none"> - prendere il portafogli alla ragazza - prendere il capello alla signora - prendere i prodotti della terra alla gente del posto | <ul style="list-style-type: none"> - prendre le portefeuille à la fille - prendre le chapeau à la fille - prendre les produits de la terre aux paysans | <ul style="list-style-type: none"> - coger (quitar) el monedero a la chica - coger (quitar) el sombrero a la senora - coger (tomar) los productos de la tierra a los lugareños |

Fig. 1 Parallel cross-linguistic variation of action verbs



| | English | Italian | French | Spanish |
|-----|--|--|--|--|
| 6. |  - take the book to the professor | - portare il libro alla professoressa | - amener le livre à le professeur | - llevar el libro a la profesora |
| 7. |  - take the dog to the beach | - portare il cane in spiaggia | - amener le chien à la plage | - llevar el perro a la playa |
| 8. |  - take the hammer to Gina - take the groceries to grandmother - take the suitcases for the customer - take the tea box for someone | - prendere il martello a Gina - prendere la spesa alla nonna - prendere le valigie per il cliente - prendere la scatola del tè per qualcuno | - apporter le marteau à Gina - apporter les courses à grand-mère - apporter les valises au client - apporter la boîte à thé à quelqu'un | - coger el martillo a Gina - coger la compra a la abuela - coger las maletas para el cliente - coger la caja del te para alguien |
| 9. |  - get the water from the fosseset | - prendere l'acqua dal rubinetto | - prendre l'eau du robinet | - coger el agua del grifo |
| 10. |  - hold the ice with the tongs - hold the material to take the hem | - prendere il ghiaccio con le pinze - prendere il bordo della stoffa per fare l'orlo | - prendre le morceau de glace avec des pincés - prendre le bord du tissu pour faire l'ourlet | - coger el hielo con las pinzas - coger el borde de la tela para coserlo |
| 11. |  - pick the flower in the garden - pick the tomatoes in the garden - pick the blackberries off the plant | - prendere il fiore dal giardino - prendere i pomodori nell'orto - prendere le more | - cueillir des fleurs du jardin - cueillir (prendre) les tomates dans le potager - cueillir des mûres | - coger la flor del jardin - coger los tomates del huerto - coger moras |
| 12. |  - catch the thief that is fleeing - the dog catches the thrown biscuit - catch the snake in the river | - prendere il ladro che scappa - il cane prende il biscotto lanciato dal padrone - prendere la biscia nell'acqua | - attraper le voleur qui s'enfuit - le chien attrape le biscuit lancé par le maître - attraper le serpent dans l'eau | - coger (atrapar) al ladrón que escapa - el perro coge la galleta lanzada por el dueño - coger la serpiente del agua |
| 13. |  - hit the bottle with the ball - hit (catch) the fish with the spear - hit the enemy in the leg - hit the guard rail with the wheel | - prendere la bottiglia con la pallina - prendere il pesce con la fiocina - prendere il nemico alla gamba - prendere lo spartitraffico con la ruota | - toucher la bouteille avec la boule de papier - toucher le poisson avec le harpon - toucher l'ennemi à la jambe - toucher la barrière avec la roue | - golpear la botella con la bola - golpear el pez con el tridente - golpear al enemigo en la pierna - golpear el vaden con la rueda |

Fig. 2 Cross-linguistic variation of action verbs

Moreover, *to take* applies in its own meaning when it extends to the action types in the gallery, and none of these types can be considered more appropriate than the others in characterizing the meaning of the verb. Each one could be a prototypic instance of the verb (Givón, 1986).

We call "General" all natural language verbs that share this property. Therefore, in the case of general verbs, ordinary language does not mirror the ontology of action, causing a huge problem for all natural language understanding tasks. As a matter of fact, the language label does not specify the referred ontological entity.

This problem becomes even more sensible when cross-language communication is concerned. The variation in Fig. 1 is also shared by the verbs roughly translating *to take* in Italian, Spanish and French. However, the translation relation does not hold if the full range of the possible actions in the extension of these verbs is

considered, as in the models of Fig. 2. For instance only *to take* can be extended to models 6 and 7 while each romance language requires another verb (*portare*, *llevar*, *amener*).

On the contrary only Italian can refer to 13 with the same verb (*prendere*), and only Italian and Spanish to 12 (*prendere* and *coger*). French and English cannot be applied in 12 and 13. These languages respectively require *attrapper* and *to catch* in 12 and *toucher* and *to hit* in 13.

In summary, no one to one translation relation between these action predicates in the four languages holds, since they are not equivalent for what regards the range of their possible extensions (hence not equivalent in intension).

2. Action Ontology and Translation

More generally, no translation relation can be established between action predicates in different languages, as far as the ontological entity referred by action verbs is not identified and there is no guarantee that two predicates in a bilingual dictionary pick up the same entity. For this

reason Action verbs are puzzling for MT, which may fail the lexical choice even for simple sentences.

For instance, according to pragmatic circumstances, the Italian sentence in (1) can be interpreted as an instance of model 1, 7, or 10 and can be translated into English respectively with *'to take / to hold / to catch*, but this information can be foreseen only if action types are identified cross-linguistically:

- (1) Mario prende il gatto
- (1') Mario takes the cat
- (1'') Mario holds the cat
- (1''') Mario catches the cat

This problem is extremely sensible in practice since action verbs are high frequency both in speech and in all basic translation tasks, but the existence of the above semantic relations cannot be predicted, since they require general ontological knowledge which is not available.

Nevertheless, the application of general verbs to the action types in their extension is productive and should, in principle, be predictable. Once one action type is identified, then we can foresee that the translation relation among predicates referring to that type in different languages holds in all instances of the type. For instance we should not expect that the translation relation holding between *prendere* and *to catch* in 12 might hold of *thief* but not of *cats*.

The Sapir-Whorf hypothesis notwithstanding, the productivity of translation through the instances of a type is proof that humans categorize those actions in the same way, despite the fact that the verbs referring to those actions in the various languages are not equivalent in intension. Therefore, Action types can be considered an ontological level that is independent from the language.

2.1. Action Ontology and lexical databases

Existing verb typologies have gone a long way in systematically categorizing verbs into classes, be it on the basis of syntactic grounds, semantic grounds, or a combination of both, by capturing the relationship between lexical properties, semantic roles and syntactic behavior.

There is a range of lexical resources and ontologies which provide information on verb meaning variation and a number of initiatives which extend the information provided according to each frame to many languages.

Verbs are an important part of WordNet (Fellbaum, 1998). Roughly 11,000 verbs are present, divided into 24,632 senses in the original English database, which has been extended to many other languages.

The Berkeley FrameNet project (Baker *et al.*, 1998) is an English resource based on Frame Semantics (Fillmore and Atkins, 1992). More recently, similar resources have been developed for several languages (German, Spanish, Chinese, Japanese, Swedish, Brazilian Portuguese). In this model, each sense of a polysemous word belongs to a different semantic frame, identified through a script-like conceptual structure that describes a situation, object or event along with its participants and their roles. Currently, FrameNet defines about 3040 verbs attached to 320 different frames.

VerbNet and PropBank exploit Levin's classification of verbs, in which syntactic frames are assumed to be a direct reflection of the underlying semantics. (Levin, 1993).

The VerbNet database (Kipper-Schuler, 2005) is a broad coverage English verb lexicon organized into semantic classes (more than 5000 verb senses, corresponding to approximately 3700 lemmas divided in 274 classes). Each verb class is constituted by a set of verbs sharing syntactic frames, thematic roles and selection restrictions. PropBank (Palmer *et al.*, 2005) focuses on the argument structure of verbs, providing a complete corpus annotated with semantic roles specifying verb alternation behaviour in Levin's sense. The lexicon contains about 3600 verbs, with quantitative data regarding their alternation patterns. "Cross-linguistic mapping" should be one of the main requirements for lexical ontologies. Since resources like VerbNet and PropBank are strongly based on the syntactic behaviour of verbs, they cannot be applied to different languages, which of course show completely different syntactic projection.

More generally, the variation in thematic structures of a general verb do not define the set of action types in its extension and cannot give an account of its variation.

For instance, the sentence in (1) can be interpreted according to models 1, 7 and 10, but the verb still assigns the same theta roles (Agent and Theme) in all interpretations.

The problems encountered by present ontologies in dealing with the categorization of action at a cross-linguistic level can be made explicit by looking to Wordnet. For instance Wordnet identifies 42 *synsets* for the verb *"to take"*. Let's focus on just three of these entries:

- a. S: (v) **take**, get hold of (get into one's hands, take physically) *"Take a cookie!"*; *"Can you take this bag, please"*
- b. S: (v) **lead, take**, direct, conduct, guide (take somebody somewhere) *"We lead him to our chief"*; *"can you take me to the main entrance?"*; *"He conducted us to the palace"*
- c. S: (v) **assume, acquire, adopt, take on, take** (take on a certain form, attribute, or aspect) *"His voice took on a sad tone"*; *"The story took a new turn"*; *"he adopted an air of superiority"*; *"She assumed strange manners"*; *"The gods assume human or animal form in these fables"*

Despite its richness, this information is hard to use for disambiguation and translation tasks not only because it originates from English, but also for theoretical reasons.

The first one is that the identification of the actual use of a verb among all its *synsets* is hard for humans. Descriptions given of each *synset* are too vague and difficult to be used for disambiguation tasks even by expert annotators (Ng *et al.*, 1999).

A second crucial reason is that the productivity of verb application cannot be guaranteed by all *synsets* in the same manner. More specifically Wordnet does not distinguish the *synsets* instantiating the proper application

of the verb (for instance *a* and *b*, correspond to models 1 and 7) from those which instantiate phraseological or metaphorical usages (for instance *c*).

Verbs have a lot of applications which depart from their actual meaning, but those usages do not constitute any productive action type. It is reasonable to foresee that the Italian verb “*prendere*” can be applied to all instances of *a* and in no instances of *b*:

(2) he takes / a cookie / a glass / a bag
(2') lui prende un biscotto / un bicchiere / la borsa

(3) he takes the car / the dog / his friend there
(3')* lui prende la macchina / il cane / il suo amico là

On the contrary this is not the case in *c*, which is a metaphorical usage of the verb. We cannot foresee any regularity in the application of the Italian verb “*prendere*” to the possible instances of *c*.

(4) he took an air of superiority
(4') ha preso un'aria di superiorità

(5) he took on strange manners
(5')* ha preso strane maniere

In summary, despite the high number of usages registered in Wordnet, there is no possibility of identifying those types that constitute the basis for a productive cross-linguistic relation. This is crucial since Wordnet interlingual indices (ILI) are viable only for *synsets* regarding productive types.

3. The IMAGACT Resource

The IMAGACT project, which has been funded in Italy within the PAR/FAS program (undertaken by the University of Florence, ILC-CNR, Pisa, and the University of Siena) uses both corpus-based and competence-based methodologies for simultaneous bootstrapping of a language independent action ontology from spontaneous speech resources of different languages.

The IMAGACT infrastructure faces key issues in Ontology Building. It grounds a productive translation relation since it distinguishes the proper usage of verbs from their metaphorical or phraseological extensions; it allows easy identification of types in the variation, it is cross-linguistic in nature, it derives from the actual use of language but it can be freely extended to other languages through competence-based judgements and it is therefore suitable for filling gaps in lexical resources.

The project is presently developed by 20 researchers (both permanent and non-permanent) and will end by 2013.

3.1. The Exploitation of spontaneous speech repositories

The first idea developed in IMAGACT is to strictly define the relevant domain of language usage from which data about linguistic reference to actions can be derived. Actions specified by those verbs that are most frequently

used in ordinary communication are also the actions which are more relevant and constitute the universe of reference for the language. The actual use of Action oriented verbs in linguistic performance can therefore be appreciated by observing their occurrence in spontaneous speech resources in which reference to action performance is primary. Spontaneous Speech Corpora have been published in the last decade and are exploited in IMAGACT to extract this information. The IMAGACT database focuses on high frequency verbs, which can provide sufficient variation in spoken corpora i.e roughly 500 verbs referring to actions which represent the full basic action oriented verbal lexicon.

IMAGACT identifies the variation of this set in the BNC spoken text and in parallel will exploit the Italian Spoken corpora in order to get a higher probability of occurrence of relevant action types.

The project foresees the annotation of verb occurrences in each language corpus (around 50,000 occurrences for each).

3.2. The IMAGACT annotation infrastructure

The corpus-based strategy relies on the identification of productive types through manual annotation. At present IMAGACT has developed a robust technical infrastructure for deriving action types from corpus occurrences. The system has been tested with real data from both the Italian and English resources. Around 180 verbal lemmas have been processed until now in the Italian corpus, generating a provisional ontology of roughly 400 action types (Moneglia *et al.*, Forthcoming). The annotation procedure has been standardized in the specs of the IMAGACT project (Moneglia and Panunzi, 2010) and it is accomplished through a web based annotation interface.

The annotation is structured in two shots leading from the occurrences of each verb in a language corpus to the identification of the action types extended therein.

The first shot foresees the standardization of corpus occurrences and then gathering of proper occurrences into types. The task is achieved in four steps:

1.1 - Generation of a simple sentence in third person representing the meaning of the instance in the corpus in a clear manner;

1.2 - Negative selection of occurrences which do not instantiate the verb in its own meaning (metaphorical or phraseological);

1.3 - Grouping of standardized proper occurrences into classes according to the number of equivalent synsets fitting with the group;

1.4 - Selection of "best examples" representing the class in all possible argument structures;

The annotator derives from the vague content provided by the oral context of verb occurrences a simple sentence that well represents the action. On the basis of this representation the annotator judges whether or not the occurrence is a proper instance of the verb.

In other words he splits the metaphorical and phraseological usages which do not instantiate the actual meaning of the verbs from productive occurrences and then classifies only the latter into types.

The decision concerning the status of the occurrence makes use of an operational test roughly derived from Wittgenstein (1953). The occurrence is judged PRIMARY if it is possible to say to somebody who does not know the meaning of the verb V that “the referred action and similar event are what we intend with V”, otherwise the occurrence is MARKED.

In accordance with this criterion, occurrences in (2) will be judged as PRIMARY, while those in (4) will be judged MARKED. Only Primary occurrences are classified into types, since they are in principle productive.

Once all instances are in standard form, the annotator identifies the action types instantiated in the corpus selecting at least one “best example” representing each type. For instance, the annotator will distinguish “John takes the glass from the table” (Type 1 of Fig 1) from “John takes the book from the assistant” (Type 4 of Fig.1), and so on. In so doing he will gather together all occurrences of the same type.

The choice of a best example heading the type (step 1.4) is crucial to test the cognitive consistency of the typology derived from corpus data. This is the main task achieved in the second shot, which is devoted to the “Validation and Annotation of types”.

The second shot is achieved in four steps:

- 2.1 Comparison of the types to ensure that two claimed types do not refer to the same action (cutting granularity);
- 2.2. Assessment that each instance of a type corresponds to the best example (productivity of the type);
- 2.3 Assignment of thematic roles and aspectual class to the best example;
- 2.4 Scripting of the type

For instance, a supervisor assesses that indeed type 1 should be distinguished from type 4 and then, faced with the best examples of a type, will judge whether or not the set of sentences gathered within the type are proper instances of it.

The linguistic properties of the type are annotated after this assessment and all instances of the type will then inherit these properties.

The annotation of verb occurrences in a language corpus ends with the scripting of each type for the production of a scene representing its best examples.

3.3. The cross-linguistic definition of the ontology of action in a Wittgenstein-like scenario

A cross-linguistic set of action types achieved through definitions agreed by linguists working on different language corpora could be considered hopeless. The experience in ontology building has shown that the level of consensus that can be reached in defining entities which are objective of language reference is very low, since the identification of such entities relies on a definition. Definitions are highly underdetermined, since they depend on the granularity of feature retrieval.

The traditional methodology will require reconciling in a unique definition all definitions given by linguists to classify the actions occurring in each language corpus. Definitely unrealistic.

The key innovation of IMAGACT is to provide a methodology which exploits the language independent capacity to appreciate similarities among *scenes*, distinguishing the *Identification* of action types from their *Definition*. Only the identification is required to set up the cross-linguistic relations. In Wittgenstein’s terms, how can you explain to somebody what a *play* is? Just point out a play and say “this and similar things are plays” (Wittgenstein, 1953).

In IMAGACT the ontology building makes use of the universal language of images which allows reconciling in a unique ontology the descriptions derived from the annotation of corpora belonging to different languages. For instance, the distinction between type 1 in Fig. 1 and type 8 in Fig. 2 is relevant in foreseeing cross linguistic variation. More specifically the same general verbs apply to both types in Italian (*prendere*) and Spanish (*coger*), while both a general verb and a more specific verb are required in French (*prendre – cueillir*) and in English (*to take - to pick*). The difference between 1 and 8 is easily recognized by humans and does not require the definition of a set of differential features, which on the contrary is radically underdetermined.

The same action sometimes has different meanings across cultures, but this restriction is not an issue for languages sharing the reference universe as those considered in IMAGACT at this stage of the work. For this reason this Wittgenstein-like scenario will be exploited to identify action types at a cross-linguistic level avoiding direct comparison.

IMAGACT will deliver a database of Action types with their language encoding through English and Italian verbs in conjunction with the set of sentences (derived from corpora) instantiating each type.

Scenes are not computable objects. IMAGACT however will provide a set of information that may ground new generation computational tools for disambiguation and MT. Crucially it will target disambiguation of natural language action verbs with respect to a closed list of productive types and will establish automatic cross-linguistic correspondences for each type. Moreover it will provide the linguistic correlations of each type in the implemented languages (argument structures, thematic structures, aspectual type, preferential arguments).

3.4. Competence-based extension to languages and Ontology implementation

On the basis of this outcome it will be possible to ask informants with a different language competence what verb(s) is applied in his language for each type, identified by a scene and by a set of English sentences derived from corpus occurrences and assigned to that scene. The informant will provide the lexical choice available in his language. Crucially, the informant will verify whether or not the choice is correct for all arguments retrieved from the corpus and assigned to that type.

The translation relation between the lexical entries in whatever language and the validated set of equivalences in IMAGACT will follow.

This work generates an enormous amount of new knowledge for Lexicography, Language typology and Translation theory. In IMAGACT the action ontology will provide equivalences for languages with high global

impact but with strong diversity in cultural tradition and linguistic tendencies (Spanish and Chinese Mandarin). Competence-based extensions are also foreseen in the future for many other languages (for instance, Hindi-Urdu, Arab, Japanese, Korean, Russian, German, Danish).

This work is conceived in a way that exploits linguistic diversity to implement the action typology. For instance, contrary to English and Italian which record a lot of General Verbs, Danish has a very specific verbal lexicon (Korzen, 2005). Therefore, we expect that action types which are relevant for Danish are not identified working on other languages. For instance the type in Fig. 3 will record a lot of occurrences of the verb *to put* instantiating the type:

- (7) John put the glass on the table
- (8) The wife put the pot on the stove
- (9) John put his dresses on the bed



Fig. 3 Action type extracted from corpus, analyzing the verb *to put* **Fig. 4** Action type derived from competence-based extension

Many languages will go in parallel with English, however this will not be the case when a Danish mother tongue informant will go through the same instances of the type. The informant will apply *at sætte* looking to the scene in Fig. 3 and will verify the consistency of this verb through the occurrences of the type. The translation will run in parallel with the same general verb *at sætte* in (7) and (8), but not in (9):

- (7') Marco har sat [stillet] glasset på bordet
- (8') Konen har sat [stillet] gryden over ilden
- (9') Moderen har lagt tøj på sengen

In (9) a different verb is strictly required. Danish, which is a language encoding *mood* in its action verbs (Talmy, 1985), applies *at lægge* in all cases where the object lies on its destination, like in Fig. 4.

Therefore, a new type will arise in the database as a function of this language-specific categorization. The new prototypic scene in Fig. 4 will be generated.

We expect a huge amount of data from this task, which will ground in a core part of the lexicon the traditional concept of "Language specific categorization".

After its first delivery the IMAGACT infrastructure will grow freely as a function of its competence-based implementation in an open set of languages.

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