Building ASLNet, a Wordnet for American Sign Language

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Abstract

We discuss the creation of ASLNet by aligning the Princeton WordNet (PWN) with SignStudy, an online database of American Sign Language (ASL) signs. This alignment will have many immediate benefits for first- and second- sign language learners as well as ASL researchers by highlighting semantic relations among signs. We begin to address the interesting theoretical question of to what extent the wordnet-style organization of the English lexicon (and those of wordnets in other spoken languages) is applicable to ASL, and whether ASL requires positing additional, language- or modality-specific relations among signs. Significantly, the mapping of SignStudy and PWN provides a bridge between ASL and the worldwide wordnet community, which comprises speakers of dozens of languages working in academic and language technology settings.

1 Background and Motivation

We discuss plans for developing ASLNet, the large-scale alignment of the Princeton WordNet (Miller, 1995; Fellbaum, 2010) and SignStudy (www.signstudy.org), a database of American Sign Language (ASL) signs. The popularity of the Princeton WordNet (PWN) has spawned wordnets in dozens of other spoken languages (Bond and Foster, 2013; Vossen, 2004), including those outside the Indo-European language family. Crossing modalities, ImageNet (Deng et al., 2009), a database created to support image recognition, contains thousands of images linked to PWN's synsets. Sign languages fall squarely within the family of human languages but communicate meaning in the visual-kinesthetic modality. Aligning the synsets of PWN (and by extension those of the wordnets in other spoken languages) with ASL signs is both a logical and challenging next step.

1.1 SignStudy

SignStudy (SS) is an online ASL lexical resource created and supported by SignSchool (www.signschool.com), an online ASL learning platform. SS is freely available to any registered user who wants to learn, explore or conduct research on the ASL lexicon.

Users can search for signs by typing an English word into a search window, which returns a video showing the corresponding ASL sign. SS will return multiple signs if there are several variants (synonyms) of a sign that share the same meaning; multiple signs will also be returned for a polysemous word form whose different English meanings correspond to distinct signs in ASL. Signs are demonstrated via videos with user-controllable pausing and playback speeds. Additionally, signs are accompanied by four annotated parameters: the dominant hand starting and ending handshapes, and the non-dominant hand starting and ending handshapes. The database is structured in terms of semantic categories (e.g., Nature) and subcategories such as Nature:Animals and Nature:Landforms. In the current version of SS, the depth of the semantic hierarchies is limited to two levels.

1.2 Benefits of SS

As a large repository of ASL signs, SS has the potential to offer a centralized platform for the ASL research community to study various aspects of that language. Supporting the study and comparison of signs along with their properties will enable the expansion of theoretical linguistics research on sign language. SS would also benefit ASL lexicography efforts by enabling the analysis of which signs (among their variants) are considered more prevalent and standard than others by various subgroups of the ASL community (e.g., native vs. non-native signers), perhaps through the implementation of a sign rating mechanism, whether via a crowd-sourced or a controlled polling process.

A deeper understanding of ASL gained from such research has the potential to improve ASL teaching resources such as those available via SignSchool, offering tools that enable users of other languages to become familiar with ASL. ASL is taught in some high schools and universities in the U.S., but older individuals and those who do not have access to adult education facilities offering ASL classes would clearly benefit from an online resource that can be accessed with a computer anywhere and anytime.

Increasing the accessibility of ASL learning resources is critical for raising the general public's awareness of ASL as it would enable improved communication accessibility among deaf ASL users and the hearing. It would also address the fact that many hearing speakers are unaware of ASL as a full language with all the complexity and expressiveness of a spoken language, including a rich lexicon and a grammar that differs considerably from English but falls well within the parameters of Universal Grammar.

1.3 Limitations of SS

SS is well equipped as a resource to assist with these broader goals with its respectable coverage of the ASL lexicon. The database currently contains 4,500+ sign videos (demonstrated by over 10 deaf and hard of hearing models) associated with 6,000+ English equivalents. Signs are annotated by 67 handshapes, 38 semantic categories, and 238 semantic subcategories. Nonetheless, SS will benefit from further additional coverage. As is the case for spoken languages, the size of the lexicon cannot be conclusively determined, in part because the notion of *word*, as familiar from a spoken language, does not map straightforwardly to *sign*. In the context of our work, we define 'word' as a unique mapping of meaning and form, regardless of modality. For example, the sign DOG[1] and the spoken form [dog], both referring to canines ("dog" in written English), can both be considered 'words', and thus part of the lexicons of English and ASL.

SS aims to be more than a flat list of signs with their English equivalents. The meanings of signs can be more clearly represented in a thesaurus-like fashion, where signs with intuitively similar meanings are interconnected. While SS has already manually grouped its current vocabulary into semantic categories and subcategories, much more structure will be added.

2 Enhancing SS with PWN Relations

A promising method for the semantic organization of SS's signs is to map them to PWN, creating ASLNet. However, it is critical to avoid the misconception that ASL is simply a signed version of English, which leads to the incorrect impression that one may develop ASLNet by the simple mapping of signs to their corresponding English words in PWN. As is the case with creating wordnets for languages other than English, ASLNet-internal additions are required to accommodate links among signs, some of which are not (and cannot) be encoded for wordnets representing the lexicon of a spoken language. With this in mind, we emphasize that our objective is to utilize the semantic structure offered by PWN to assist with the semantic organization of ASL signs and their linking to corresponding senses in other languages with wordnets.

There are multiple benefits resulting from a mapping of ASL signs to PWN entries. Deaf and hearing learners of ASL can explore the ASL lexicon by following the links in multiple, intuitive ways. For example, if the signs HAND and FINGER are linked to PWN synsets containing (the corresponding senses of) *hand* and *finger*, the semantic relation between these two words (meronymy, the part-whole relation) that is encoded in PWN will be transferred to the signs. SS does not need to independently encode such relations among signs, so long as signs and PWN words are semantically equivalent.

A structured lexical resource for ASL will offer major pedagogical benefits and enable semantically-driven learning of ASL (Miller and Fellbaum, 1992). It will support language acquisition by Deaf children by enabling them to quickly acquire the meanings of new signs. For example, the signs LEGISLATURE and JUDICIARY could be linked to the sign GOVERNMENT by the meronymy relation; the signs EX-

[1] In this paper we use the convention of writing ASL signs in all capital letters.

PENSIVE and CHEAP by the antonym relation, etc. Children's books designed to foster word learning commonly present words in such semantically related groups. Second-language students of ASL will be able to expand their ASL lexicon by diving into a semantic rabbit hole as they discover a sign that leads them to semantically related signs, and so on. Entire lessons could be organized semantically so that critical areas of the lexicon are quickly filled out with meaningfully related signs.

Perhaps the most important benefit of linking ASL to PWN is the immediate connection to dozens of wordnets in other languages. PWN can be thought of as the hub to which wordnets in many languages are linked. Departing from a given signed word will allow one to go from the corresponding English word to its equivalents in Spanish, Basque and Hindi, for example. Additionally, the link between PWN and ImageNet raises interesting possibilities for exploring questions of iconicity in ASL (Perniss et al., 2010).

3 Related Work

We are aware of only one effort to link wordnets to a database of signs. (Prinetto et al., 2011; Shoaib et al., 2012) describe plans for developing a Sign Bank for Italian Sign Language (LIS) and its alignment to MultiWordNet (Pianta et al., 2002), a lexical database for Italian, Romanian, Spanish, Portuguese, Latin and Hebrew modeled on, and linked to an early, smaller version (1.6) of PWN that is no longer the standard for natural language processing applications. However, while the concept of LIS was developed and described in (Shoaib et al., 2012), to the best of our knowledge, the LIS Sign Bank was not in fact created.

4 Units of Meaning

Both SS and PWN are databases whose atomic units are form-meaning mappings. However, there are inherent technical challenges to aligning such pairings across different modalities. Spoken and written words are discrete units of form-meaning mappings. By contrast, signed words are expressed through movement in continuous space. This allows signers to modify a given meaning in a continuous manner in many cases; signers are not necessarily limited to the words of a spoken language that divides a range or scale into discrete steps. Additionally, while there also exist signs with quasi-discrete differences in meaning, boundaries between these meanings may not always be clear-cut due to the continuous nature of signing. Consequently, a successful mapping between discrete spoken words and continuous signed words requires a careful analysis of the meaning(s) of ASL signs.

4.1 Gradability

Residing in continuous space, ASL signs have a vast parameter space that results in many signs having highly variable senses. One consequence of this is a large number of signs being gradable. For example, basic lexical signs, such as SNOWING, may be endlessly modified to assume slightly modified senses (e.g., "snowing" vs. "snowing heavily"). The lack of discrete steps in such modifications makes it difficult to map such signs to discrete synsets. In fact, such mapping efforts may reveal the rich, fluid way in which troponyms and hyponyms are expressed in ASL.

One possible solution, at least for gradable signs, is to distinguish between gradable and complementary signs. For gradable concepts, we propose creating a special construction in ASLNet that associates groups of signs with numerical ratings to indicate their location on their shared scale. Discrete synsets can then be linked to this grouping. For NLP applications, one could add threshold ranges to ASLNet queries that will return the signs that, for example, fall between intensities 5 and 7 on a 10-point scale. In fact, ASL instructional material (e.g., textbooks) typically simplify the scale to three degrees: less, normal, more. This three-way classification may be sufficient for ASLNet purposes.

Note that a one-dimensional gradability scale is assumed here; further analysis may reveal the need for higher-dimensional scales to characterize signs with more than one gradable aspect. We anticipate this to be the case for verbs, where the troponymy relation distinguishes among verbs that can elaborate the common event along different dimensions. For instance, the sign WALK may be modified along a scale corresponding to walking speed (cf. English "run" and "amble") and along another scale corresponding to step length (cf. English "mince" and "stride").

4.2 Classifier Constructions

The continuous-space nature of ASL also manifests itself via classifier constructions. Essentially, they are certain handshapes that are associated with different semantic classes (e.g., size, shape, action, etc.). Thus, when these handshapes are paired with specific sign parameters or used in certain sentence constructions, they can be used to communicate nuances in meaning and provide highly detailed descriptions (of objects, actions, etc.). As a simple example, classifiers may be used to elaborate the meanings of basic lexical nouns. For instance, one possible way to sign "tome" is to first produce the lexical sign meaning "book" followed by a classifier construction that indicates the referent (the book) possesses the property of substantial thickness. Additionally, classifier modifications are often gradable; the production of the "thickness" classifier may be adjusted on a thickness scale to change the description of the book from that of a tome to that of a pamphlet.

Thus, signs that include classifiers would benefit from being encoded into ASLNet in a manner that indicate the classifier(s) used and their position(s) on the relevant scale(s). This will allow for a more complete documentation of the semantic meaning of a particular sign and how its components contribute to the meaning of the sign. Doing so will assist with the semantic linking of signs within ASLNet as discussed below.

4.3 Non-Manual Signals

Expressions of gradability and classifiers often involve the use of non-manual signals (NMS), which consist of various facial and body movements that accompany signs. They serve many purposes, including modifying individual signs and indicating sentence structure. In the context of ASLNet, we are primarily interested in NMS that are an integral component of a sign and NMS that modify the meaning of signs. For the former, certain signs require a particular NMS (namely, a mouth morpheme) to assume a particular meaning. Thus, for STRUGGLE the handshapes and their movements are almost always accompanied by a STA-STA mouth movement. For the latter, NMS can be used to indicate the precise meaning of a sign; the classifier construction used in TOME may be paired with different NMS to indicate whether a particular tome is an average tome (neutral face), or a very thick tome (incorporating a CHA mouth movement).

In developing ASLNet, it is important to distinguish between non-grammatical and grammatical NMS. Non-grammatical NMS are analogous to voice inflections; an ASL speaker may assume a happy facial expression when conveying happy news. While such expressions do convey meaning at the conversational level, they do not directly affect the meaning of individual signs, and thus are not of interest in the context of ASLNet. This is in contrast to grammatical NMS (as discussed above), which are more structured to the extent that they modify the meaning and function of signs.

4.4 Lexical Gaps

While certain ASL signs may have a clear English correspondence in PWN, there are lexical gaps in both languages, as is the case for any language pair.

As an example, the sign TRUE BUSINESS, which may be literally translated as "true business", is often used to emphasize the authenticity of a statement or to introduce a surprising twist to a previous statement. There is no obvious lexical equivalent in English, though various (highly context-dependent) translations exist. Such gaps are also also prevalent in certain usage cases involving classifiers. For instance, classifier-based signs such as CL-"peeling a banana" and CL-"close a refrigator" do not have lexeme status in English, where they are freely composed. While such signs obviously are to be included in ASLNet, they will not map onto a single synset in PWN. There are also many examples where the reverse is true, i.e., a simplex word in English requires multiple signs in ASL that speakers do not consider a lexical unit. For instance, the English word "concierge" requires signing out a full phrase analogous to "the hotel employee who assists guests".

A solution for handling crosslingual lexical gaps is to add a placeholder, without a word, for signs and words in the network that show the gap, either PWN or ASLNet.

5 ASLNet-Specific Links

As ASL possesses linguistic properties distinct from those of spoken languages such as English, ASLNet-internal additions are required to accommodate links among signs. Without those modifications, ASLNet runs the risk of projecting ASL into an incompatible framework, preventing its study without biases towards spoken languages.

5.1 Phonological and Lexical Links

ASLNet requires the encoding of information pertaining to the five generally recognized parameters of ASL (handshape, location, movement, orientation (palm), and non-manual signals) for each sign. Links may then be established between signs that share common phonological properties.

The five parameters are analogous to phones in a spoken language. In isolation, phones like [k], [a] or [t] carry no meaning, but when composed into a morpheme or word, they assume a meaning ([kat] = 'cat'). The same is true for sign language parameters: individual parameters of signs combine to give the whole sign its meaning. Thus, modifying one parameter of a given sign will result in a different sign that may or may not have a related meaning. While this seems analogous to substitution of a different phoneme of a given word (*hat-cat-car*), the meanings of such words are not usually similar for spoken languages.

The framework for such a phonological categorization has been demonstrated by Caselli et al. (2017) with the development of ASL-LEX, a broad lexical database of approximately 1,000 signs. Each sign in ASL-LEX is coded with six phonological properties (sign type, selected fingers, flexion, major and minor location, and movement). An ASLNet-specific lexical encoding is also likely beneficial, as demonstrated by ASL-LEX, where signs are additionally coded for four lexical properties: initialization, lexical class, compounding, and fingerspelling.

By utilizing aspects of ASL-LEX's design and structure as a model, ASLNet will be able to incorporate ASL-specific phonological and lexical properties necessary to develop some of the ASLNet-internal links. ASLNet can then build upon the work done by Caselli et al. by introducing the additional dimension of semantic links by virtue of its integration with PWN.

5.2 Other ASLNet-Specific Links

There are additional ASLNet-specific links that ASLNet would likely benefit from including. An example is the close relation between the members of ASL noun-verb pairs. There are many signs that can simply switch between noun and verb forms by, for instance, changing the number of movements, such as chair (CHAIR [2x]) and sit (CHAIR [1x]). This parallels the many noun-verb pairs in English related by zero morphology (love, drive, travel, Google, etc.). Encoding such pairs in ASLNet would allow for the comparison of the relations among the different part-of-speech forms of ASL signs with other languages and whether certain relations are more prevalent for certain semantic categories, e.g., teleologically related noun-verb pairs for artifact nouns.

Additionally, signs containing classifier constructions should be linked if they have similar classifiers since such signs may have similar meanings. For instance, recalling our TOME example from earlier, the classifier used to indicate the thick nature of a book would be applicable to signs relating to a "beam" as in "wooden beam"; they are both thick objects. This is analogous to sound symbolism in English, as in many words beginning with [gl] ("gleam", "glitter", and "glossy") that all seem to have a meaning related to light. Combining these classifier links, along with the phonological and lexical links discussed above, with purely semantic links from PWN will allow for the exploration of phonesthesia in ASL (i.e., the non-accidental relation between form and meaning).

6 Implementation

We discuss methods and steps required for building ASLNet.

6.1 Crosslingual Wordnets

After PWN gained widespread popularity, wordnets were built in a number of different languages. EuroWordNet (Vossen, 2004) comprises eight European languages, including Estonian and Basque, which are genetically and typologically unrelated to Indo-European languages.

An important goal was to connect all wordnets to one another, so that equivalent words and meanings could easily be identified. EuroWordNet took PWN as its hub to which each new wordnet was mapped. In some cases, the wordnet developers simply translated the English synsets into their language; in other cases, wordnets were initially built up independently and later merged with the English version. Not all languages lexicalize the same concepts, and for words that have no English equivalent a simple record was added to PWN pointing to and from the language-specific words. In this way, PWN became the union of all concepts lexicalized in all wordnets, but not shared by all. Consequently, the structure of EuroWordNet permits one to find equivalent words and meanings in all eight languages by going via PWN, making it a valuable tool for crosslingual study and applications.

Since the techniques described by (Vossen, 2004) proved successful for connecting PWN to non-Indo-European languages, it is reasonable to believe that they are applicable to the case of ASL, which is genetically unrelated to English. The only unknown is whether and to what extent such techniques also work across modality differences (spoken vs. signed).

6.2 Proof-of-Concept Demonstration

Following the methods described by Vossen, we propose to use a hybrid approach in building ASLNet, starting first by directly mapping straightforward cases such as many common nouns. We then encode words existing only in ASL and ASLNet-specific semantic relations among signs, such as noun-verb mappings and gradable groups, within ASLNet. Once we have accommodated ASLNet-specific entries and links, the next step is to merge these with PWN.

Thus, as our first step we plan to develop a proof-of-concept demonstration of ASLNet (ASLNet V1.0) by starting with lexical ASL nouns. Advantages of working with lexical nouns include their relative ease of encoding and more straightforward PWN mappings by virtue of their lexicalized nature. This is in contrast to verbs whose expression differs significantly in ASL. To guide ASLNet V1.0 development, we intend to draw lexical nouns from existing PWN noun categories that have a rich hierarchical structure, such as vehicles, artifacts, and food. Starting with these categories will allow for the increased likelihood of observing novel semantic relationships between ASL signs early in ASLNet development, providing opportunities for evaluating the success of our development technique.

6.2.1 Technological Infrastructure

Steps have already been taken to develop a preliminary system for mapping SS signs to PWN. The structure of the SS database now allows for the association of ASL signs with their corresponding English equivalents. These equivalents are in turn linkable to PWN synsets. Thus, the links associated with those equivalents will be automatically inherited to SS from PWN.

SS has developed a simple web application to allow for computer-assisted manual linking of SS signs to PWN synsets and the assignment of POS labels. This "WordnetMapper" tool[2] utilizes the existing English equivalents of SS signs to query PWN for the purpose of suggesting possible additional English equivalents as well as PWN synsets to map to. Manual mapping is also possible via this application.

6.2.2 Development Procedure

A relatively complete and functional prototype will be developed by following PWN groupings and systematically filling out all or most of the terms in PWN (e.g., "eyelid" and "nostril" are parts of "eye" and "nose", respectively).

A team of contributors will supply any additional signs necessary for filling out of specific corners of the ASL lexicon within SS. Each additional sign will be accompanied by filmed demonstration by a Deaf and native signer of ASL. Fluent ASL signers experienced with ASL-English translation will then assist with the phonological and lexicographical encoding (including ASLNet-specific links) of those signs into the SS database, including their mapping to their corresponding PWN synsets.

6.2.3 Lexicography Considerations

As much is not yet known regarding developing a wordnet for a sign language, the development process for ASLNet V1.0 will be carefully monitored and documented by the development team to generate data that will guide and inform the subsequent development of ASLNet.

ASL nouns that resist straightforward mapping to PWN, such as those without direct equivalents in English will be recorded with placeholders to mark lexical gaps in English. The same procedure will be applied to English nouns with no obvious ASL lexical equivalent.

As ASL signs are subject to significant regional and articulation variations, special attention will be given to adding as many synonymous signs as possible in order to make ASLNet representative of ASL. The equivalent of such signs in English are words like "hoagie", "submarine", "po'boy", "hero", and "grinder". Such regional variations are usually encoded in PWN as synonyms (members of one synset); sometimes, the "gloss" names the region where a specific term is used. Thus, in

[2]WordnetMapper is still in the evaluation stages and is currently not publicly available.

ASLNet such signs will be manually grouped together as variants of the same sign (and sense).

Special attention will be given to polysemy, especially where it is interesting, as in the case of metaphors, when signs for inclusion in ASLNet are recorded. For example, filming the sign for "line" as a queue, will accompany filming a sign for "line" as a long, narrow bar. Incorporating such data may make ASLNet V1.0 more versatile in identifying interesting directions to pursue in the study of systematic polysemy in ASL during subsequent development cycles.

The encoding of non-manual signals (NMS) will likely be challenging. In particular, it is not always clear what constitutes grammatical or non-grammatical NMS. Thus, for the purposes of ASLNet V1.0 the lexicographers will concentrate on signs that are not usually subject to modifications by NMS (i.e., many lexical nouns).

7 Future Work

Once ASLNet V1.0 is completed, the resulting wordnet will be analyzed for any novel characteristics and properties. These results will be reported along with an analysis of our proposed development procedure and its effectiveness.

Along with remedying any difficulties encountered during V1.0 development, building V1.1 will include identifying the mapped nouns that belong to noun-verb pairs along with the consideration of modified lexical nouns (e.g., with the use of classifier constructions). Such mappings are likely to be challenging for reasons discussed in Section 4. V1.1 will be followed by subsequent versions that incorporate mappings for increasingly complicated aspects of ASL, particularly those that differ significantly from spoken languages. Once mapping techniques have been developed and proved viable for the core aspects of ASL, large-scale lexical expansion of ASLNet may then commence. Such work may lead to ASLNet becoming a part of the Collaborative Interlingual Index (CILI), a means of linking wordnets without depending on PWN's semantic structure (Bond et al., 2016; Vossen et al., 2016). CILI integration may be beneficial in the face of lexical gaps as well as differences in word encoding and linking between ASL and English.

It is also important to be mindful of the fact that sign languages are not universal; there exist many other sign languages distinct from ASL. As the linguistic properties of other sign languages may not be entirely identical to those of ASL, it is rewarding to develop the structure of ASLNet such that it is as general as possible with regard to sign languages so that this work may give rise to similar research opportunities with other sign languages without unintentionally introducing a bias towards ASL. This is comparable to how PWN led to the development of wordnets for additional languages.

8 Conclusion

This work opens many interesting avenues for research. As discussed previously, developing ASLNet will provide insight into lexical gaps between ASL and English. With the inclusion of ASL verbs, ASLNet will permit the exploration of verb troponymy within ASL. By highlighting semantic relationships between signs, ASLNet may also offer insights into many properties of ASL, including systematic metaphoricity, compounds, idiomatic expressions, compositionality and similarities, and iconicity. Furthermore, since ASLNet will be linked to PWN, and in extension, wordnets for many other languages, comparisons of these linguistic properties may be made between ASL and other languages.

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