Abstract

The Universal Knowledge Core (UKC) is a large multilingual lexical database with a focus on language diversity and covering over a thousand languages. The aim of the database, as well as its tools and data catalogue, is to make the somewhat abstract notion of diversity visually understandable for humans and formally exploitable by machines. The UKC website lets users explore millions of individual words and their meanings, but also phenomena of cross-lingual convergence and divergence, such as shared interlingual meanings, lexicon similarities, cognate clusters, or lexical gaps. The UKC LiveLanguage Catalogue, in turn, provides access to the underlying lexical data in a computer-processable form, ready to be reused in cross-lingual applications.

1 Introduction

A recent challenge in computational linguistics has been the development of efficient multilingual and cross-lingual techniques for language understanding and processing. In terms of solutions, a mainstream, yet often implicit assumption has been that shared meaning unites languages beyond superficial differences in lexicon and grammar: after all, humankind on the whole has been successful in getting ideas across linguistic borders. Hence the recent trend of massively multilingual resources—lexical databases, cross-lingual transfer matrices, pre-trained multilingual language models—exploiting a common meaning-based mapping across linguistic units.

Linguistic diversity remains, nevertheless, a key concept insomuch as it refers to deep-running, irreducible, meaning-level differences across languages and underlying cultural concepts. To take real examples from state-of-the-art machine translation, syntactically correct but semantically absurd outputs such as ‘my older brother is younger than me’ or ‘this raw rice is tasty’ are not rare exceptions but recurrent consequences of diversity: the diverging ways languages express culturally significant concepts such as brother or rice. While phenomena such as lexical gaps (Lehrer, 1970), culturally diverse terminology, or the varying relevance of the notion of word itself across languages are not unfamiliar to us computational linguists, such a general and intuitive understanding is hard to translate into actual ‘diversity-aware’ computational applications, not the least because of the lack of formal datasets that would provide such information.

Lexical typology has described and catalogued many of such phenomena (Koptjevskaja-Tamm et al., 2015). A few online databases also provide contrastive data, sometimes over thousands of languages (Dryer and Haspelmath, 2013; Rzymski et al., 2020; Holman et al., 2011). These databases are rarely used in the NLP community, probably because they are often targeted towards historical linguistics and use phonetic representations of words or are limited to a few hundred core concepts. Yet, our position is that typological data can and should be reused for computational purposes, provided that they are meaningfully integrated with existing resources on contemporary language.

Computationally-oriented resources that address language diversity or linguistic typology have so far been concentrating on multilingual morphosyn-
tax (Ponti et al., 2019; Batsuren et al., 2021b; Nivre et al., 2016). On diversity in lexical semantics, only a few studies (Giunchiglia et al., 2017) and sporadic data have been available for specific languages, such as a few hundred lexical gaps in Hebrew (Ordan and Wintner, 2007) or in Italian (Pianta et al., 2002). Large-scale multilingual lexical databases (MLDB), such as BabelNet (Navigli and Ponzetto, 2012) or the Open Multilingual Wordnet (Bond and Foster, 2013), only model shared meaning and thus do not offer data on lexical diversity.

The Universal Knowledge Core (UKC) database and system presented in this paper provides computer-readable cross-lingual lexical data, covering both the common and the diverse among more than a thousand lexicons. The data is being made available for download from the UKC LiveLanguage catalogue1, while the UKC website2 provides a set of interactive tools that allow both high-level visualisations and an in-depth exploration of diversity data. The rest of the paper provides an overview of the UKC database structure and contents, the online tools, and the data catalogue.3

2 A Multilingual Lexical Database on Language Diversity

Among existing large-scale MLDBs, those with a published formal, computer-exploitable data model—such as the Open Multilingual WordNet, BabelNet, or EuroWordNet (Vossen, 1997)—concentrate on language unity, representing shared meanings through linking together words with the same meaning across languages. The UKC simultaneously enriches existing representations of language unity and introduces language diversity as formal data, both in terms of lexical model and actual content.

The UKC data model, the theoretical underpinnings of which have been exposed in (Giunchiglia et al., 2018), is illustrated in Figure 1. On the top of the figure, a supra-lingual concept layer contains hierarchies of concepts that represent lexical meaning shared across languages. Concepts thus act as bridges across languages. The only criterion for a concept to be present in the concept layer is that it is lexicalised by at least one language.

The bottom lexicon layer consists of language-specific lexicons. As in other lexical databases, these provide lexicalisations for concepts, such as the English ‘rice’ and the Italian ‘riso’ for the concept of rice in Figure 1. Beyond lexicalisations, however, the UKC lexicons also provide rich cross-lingual information on language unity and diversity through the following constructs.

Lexical gaps. As mentioned in the introduction, if not addressed properly, lexical untranslatability negatively affects the performance of cross-lingual applications. Erroneous Google translations, such as the Hungarian sentence ‘A bátyám három évvel fiatalabb nálam,’ meaning ‘my older brother is three years younger than me,’ are systematically produced due to non-existent equivalent translations, in this case for brother Hungarian.4 Likewise, as shown in Figure 1, English has no single word for raw, uncooked rice while Swahili has no word equivalent to the general term rice. The UKC provides evidence of

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1[http://www.livelanguage.eu](http://www.livelanguage.eu)
2[http://ukc.datascientia.eu](http://ukc.datascientia.eu)
3See [http://youtu.be/b90SrCjitCw](http://youtu.be/b90SrCjitCw) for a video.

4Apart from the laborious and thus rarely used fiútestvér.
untranslatability by representing lexical gaps inside lexicons. Such information can be used, among others, to indicate the absence of equivalent terms to downstream cross-lingual applications.

Cross-lingual sense relations. Beyond providing shared word meanings as other MLDBs do, the UKC represents a richer set of interlingual connections between word senses. For example, in Figure 1, the English ‘rice’ and the Italian ‘riso’ are connected through a cognate relationship. Such information can be exploited as evidence of cross-lingual similarity, e.g. as seeds in cross-lingual tasks such as bilingual lexicon induction (Batsuren et al., 2021a).

Metadata on language diversity. Beyond standard typological metadata such as language phylogeny or the geographical locations of speakers, the UKC also integrates cross-linguistic metadata computed from its own lexico-semantic content. Based on cross-lingual cognate relationships, we computed large-scale lexicon similarity data across 27 thousand language pairs over 331 languages. Lexicon similarity (Bella et al., 2021) formally characterises the extent to which the vocabularies of two languages ‘resemble each other’, taking differing writing systems and orthographies into account. This metric has, in our view, a better potential in predicting the success of cross-lingual tasks (such as transfer learning or joint supervised training) than language phylogeny, as it is based on the overlaps of contemporary lexicons as opposed to historical relatedness.

Language-specific word meanings. Diversity also means acknowledging our partial understanding of how specific languages conceptualise lexical meaning and the ultimate impossibility of an exhaustive interlingual model. The UKC is the only lexical database to allow the co-existence of shared and language-specific word meaning hierarchies, inside the concept layer and the lexicons, respectively. Figure 1 shows culture-specific words and meanings (of rice-based foods) represented inside the Kannada lexicon, not yet integrated into the shared concept layer.

Language-specific lexical relations. Lexical relations within individual languages are sometimes part of lexical databases, such as antonymy or derivation in the Princeton WordNet (Miller, 1998). The UKC introduces relation types not typically part of lexical databases—such as metonym-of or homograph-of—and provides corresponding relation instances in multiple languages.

Table 1 shows the current contents of the UKC (as of January 2022) in terms of the data types enumerated above. Concepts and concept relations were initially derived from the Princeton WordNet, as in all other MLDBS, but then extended with 400 new concepts and 490 new relations (research awaiting to be published). We obtained lexicalisations from Wiktionary, NorthEuraLex (Dellert et al., 2020), the Native Languages of the Americas, as well as the wordnet resources cited at the end of our paper. Lexical gaps were obtained mostly through our original research (about 18k

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5Cognates are words in different languages that sound the same and have the same (or similar) meaning due to a common etymological origin.

6http://www.native-languages.org
exploring diversity data

3 Exploring Diversity Data

The website of the UKC database provides browseable online access to the full database contents, data visualisation tools, extensive information on related projects, publications, source materials, as well as example downstream services, such as word translation between any two languages or multilingual word sense disambiguation (to be released soon).

A major feature of the website is the interactive exploration of lexicons and diversity data. The user can browse: (1) linguistic metadata of the 1.2k lexicons, selecting the language from an interactive map (Figure 2) or by name; (2) within a language, all meanings of a word typed in by the user; and (3) lexicalisations and gaps of a concept in the current language and in all languages of the world.

relating to diversity-rich domains such as kinship and colours, not yet published, but also 600 gaps from (Bella et al., 2020), and in a minor part from the few third-party resources providing such information (Pianta et al., 2002; Ordan and Winter, 2007). We computed cross-lingual sense relations from UKC data, reusing our method published in (Batsuren et al., 2019a, 2021a). Language-specific sense relations were obtained in a minor part from wordnets providing such data (48k relations), and in a major part from our own research on multilingual morphology (Batsuren et al., 2021b) (770k derivations in 16 languages) and metonymy (not yet published, 25k metonyms in 191 languages). Finally, lexicon-level metadata on language diversity combines online sources (Dryer and Haspelmath, 2013) with results of our own research on the similarity of lexicons (Bella et al., 2021).

| Content type                        | Data size |
|-------------------------------------|-----------|
| Languages                           | 2,176     |
| Concepts                            | 106k      |
| Concept relations                   | 109k      |
| Lexicalisations (word senses)       | 2.8M      |
| Lexical gaps                        | 24k       |
| Cross-lingual sense relations       | 8M        |
| Language-specific relations         | 840k      |
| Lexicon-level diversity metadata    | 30k       |

Table 1: UKC contents by type and their provenance.
The right-hand side, finally, shows the concept in the context of the concept hierarchy, shown as an interactive graph: the currently observed concept blueness, as well as the parent (broader) and child (narrower) concepts. Other lexicosemantic relationships (e.g. meronymy and metonymically related concepts) are also shown when they exist. While for usability reasons the graph only displays a part of the full hierarchy, it is navigable, allowing the entire concept graph to be explored in the currently selected language. Changing the language is as simple as clicking on the map or selecting it from the drop-down in the upper left corner of the screen. Colours in the graph are indicative of language diversity: they show whether a concept is lexicalised in the current language (dark-coloured nodes), are missing from its lexicon (light-coloured nodes), or are lexical gaps (black nodes).

4 Visualising Language Diversity

Beyond the fine-grained word and concept exploration presented in the previous section, the UKC website also offers visualisation tools that allow humans to grasp diversity both in its globality and from different angles. Currently the following tools are provided, three of which we present below: (1) cognate diversity clusters; (2) colexifications; (3) a gap explorer for a fixed set of domains that are lexically diverse; (4) lexical similarity graphs; and (5) visual statistics.

Cognate diversity clusters. This tool shows cognate clusters on the map for a given concept selected by the user, computed from cognate data inside the UKC. In Figure 4, the concept of fish is selected: each dot represents a lexicon that contains a word for fish. Two dots are of the same colour if the two words are cognates of each other. For example, the English ‘fish’ and the Italian ‘pesce’ are within one cognate cluster (in light green in the figure) while the Hungarian ‘hal’ and the Finnish ‘kala’ are in another cluster (in turquoise). The number and distribution of clusters for a given concept provide information about its universality or diversity: coffee is a so-called universal concept while woman is an extremely diverse one.

Lexical gap explorer. Certain domains—such as kinship, food, colours, or body parts—are known by linguists to be lexically diverse, for reasons related to culture, geography, but also grammar and other factors (Lehrer, 1970). The gap explorer tool displays a full concept hierarchy for a domain or subdomain selected by the user. Figure 5 shows the UKC concept structure of the subdomain of siblings from the kinship domain. For the language selected (Danish in the figure), the tool displays existing lexicalisations, indicates incompleteness (missing word), and provides known lexical gaps. This allows for quick comparisons of how different languages lexicalise (or not) a given domain. For example, for the cousins subdomain that consists of 67 concepts, English only lexicalises the root concept cousin with all other concepts as gaps, while South Indian languages provide no less than 16 distinct words depending on the age, sex, and lineage (patrilineal/matrilineal) of the cousin.

Lexical similarity graphs. Relying on the extensive lexical data inside the UKC, we compute pairwise similarities between languages based on the amount of shared cognates, using the method described in our recent paper (Bella et al., 2021). In order to interpret the resulting similarity data for humans, i.e. provide a global overview of lexical similarity, we compute a dynamic graph visualisation where nodes are languages and edge lengths are proportional to lexical similarities. The graph computation relies on a physical model of attraction and repulsion among nodes, using the ForceAtlas2 library (Jacomy et al., 2014). We provide two distinct colourings for the same graph: one based on language families (shown in Figure 6) and the other based on geographical distance. These graphs visualise how the similarity of contemporary lexicons correlates with (historic) phylogeny and with the geographical closeness of speakers. As a way to make language evolution visual, we also provide the equivalent graph computed over data from historical linguistics, obtained from the ASJP database (Holman et al., 2011). Insights gained from these graphs may also help computational linguists predict the performance of automated tasks that involve some form of lexicon mapping (e.g. bilingual lexicon induction or machine translation) over specific language pairs.

5 The LiveLanguage Data Catalogue

As a complement to online exploration, we are also making available the contents of the UKC for computational applications. While an open, fine-grained, API-based access to the data is planned as future work, we are already in the process of publishing data for download through the UKC.
Figure 4: Cognate clusters for the concept of fish.

Figure 5: Detail of the grandchild subdomain as lexicalised by the Danish language.

Figure 6: Detail from the lexical similarity graph coloured according to language families.
LiveLanguage data catalogue.\footnote{http://www.livelanguage.eu} The catalogue, accessible from the website through any of the numerous download links, provides access to the UKC data through multiple modalities. Accordingly, the structure of the catalogue, shown in Figure 7, consists of (1) cross-lingual datasets from projects related to the UKC; (2) individual lexicons that incorporate all types of data (as in Section 2) that describe a single language; (3) lexicon sets consisting of multiple lexicons as well as of cross-lingual relationships among them. All datasets are published in full respect of the licensing constraints of their constituting resources; data that disallow redistribution are excluded from the catalogue.

**Raw data on cross-lingual diversity.** These datasets, produced by the authors as ongoing or past projects on diversity, cover domain-specific lexical gaps, multilingual morphology, lexical similarity, and cognate relationships. Datasets are distributed in their original (e.g. tab-separated) formats, with concepts linked to Princeton WordNet 3.0 identifiers for interoperability with third-party data.

**Individual lexicons.** These datasets are produced as language-specific ‘cross-sections’ of the full UKC data. Their added value lies in the integration of multiple sources—words from wordnets and Wiktionary, language-specific morphological and lexico-semantic relationships, gaps—into a single formal representation. These datasets will be provided in multiple formats (under development), including the ISO standard Lexical Markup Framework (LMF) format as well as OntoLex.

**Lexicon sets.** The notion of language diversity gains full significance across languages. Consequently, the development of an online service is underway to allow the simultaneous download of multiple concept-aligned lexicons as a single multilingual resource. The service will export multilingual data from the UKC database in real time. Such datasets will be directly exploitable in cross-lingual training and evaluation tasks.

### 6 Conclusions and Future Work

With the UKC database, website, and data catalogue, we hope to contribute to the exploitation of language diversity as computational data. All components of the system are going through a rapid evolution: the database contents in terms of language support, lexicon correctness and completeness, the data exploration and visualisation tools, a new set of demonstrators, APIs, and downloadable datasets are continually being created and extended. At the same time, the exploitation of diversity data to improve state-of-the-art cross-lingual applications is a research direction that we expect to gain importance in the near future.

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