Digital Dictionary Database

A central database for Slovene.

Application domain and data model

Overview of the application domain and data model.

Domain and data model links

Links with relevant resources:

Resource	Version	Date	URL	Notes
Top-level overview	N/A	various	url	Top level domain overviews are spread over various papers
Presentation	N/A	28.09.2020	url	Based on data model v1.5; satellite databases obsolete
Code repository	N/A	N/A	url	Python/Django project; ask Simon Krek for access
Data model	v1.16	16.04.2024	png, mwb	
Database dump	v3.32	07.06.2024	sql	

Domain overview

Top level domain overviews are published in various papers.

These are some of the relevant papers (some may contain partially outdated data):

- Slovar sodobne slovenščine: Problemi in rešitve
  - Oblikoslovne informacije v sodobnih slovarskih priročnikih
  - Leksikon besednih oblik Sloleks in smernice njegovega razvoja
  - Tehnološka izvedba sodobnega digitalnega slovarja
  - Leksikografski proces pri izdelavi spletnega slovarja sodobnega slovenskega jezika
  - Slovarski zgledi
  - Oznake: slovarska baza in slovar
  - Homonimija in večpomenskost: od teorije do slovarja
  - Specializirana leksika v splošnem slovarju
  - Uporabniške raziskave za potrebe slovenskega slovaropisja: prvi koraki
  - S pomočjo uporabniških jezikovnih vprašanj in mnenj do boljšega slovarja
- Predstavitvena stran Slovarja sodobnega slovenskega jezika

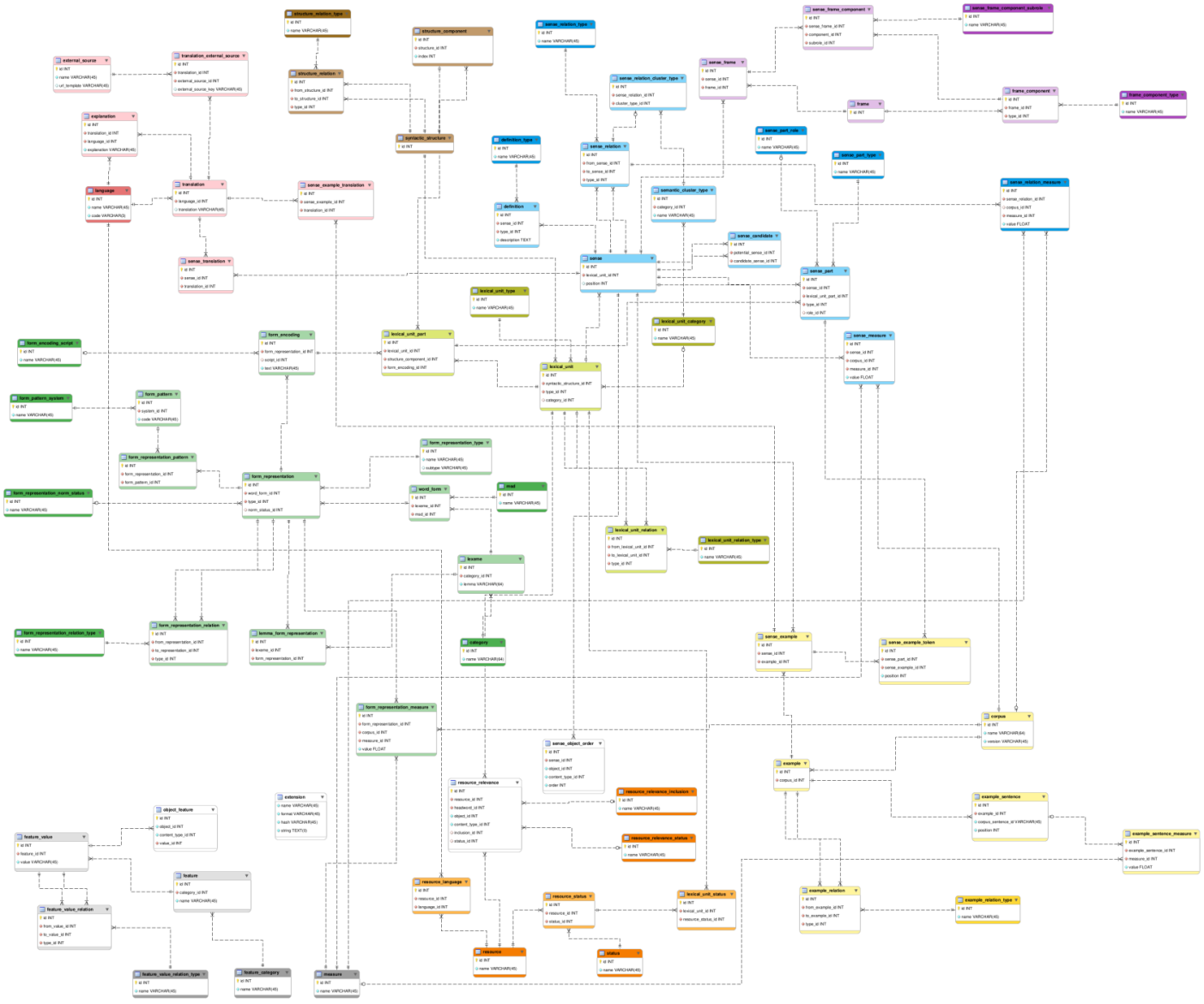
Data model

The central entity types of the datamodel are lexical units and senses. They connect the morpho-syntactic and semantical data in the data model. In essence the model is designed to be a multilingual model, however, currently it is used as a monolingual model that connects with multilingual data (which does not have the same level of granularity) via special entity types.

On the top level the model can be divided into clusters (color-coded in the model):

- lexical units (olive green)
- senses (blue)
- word forms (forest green)
- syntactic structures (brown)
- corpus examples (yellow)
- sense translations (red)
- sense frames (violet)
- resource connections (orange)
- generic features (grey)
- entity types that reference other entity types via meta-attributes (white)

The corpus data is not contained in the database itself, but is referenced and accessed via a concordancer. Some data (e.g., structure details) is defined in XML, which is used in existing processing pipelines. This data is stored in a separate generic SQL table, but can be remodeled if needed.



Contents

Overview

Purpose and state of this document

This document is intended for technical users who are working with the DDD model and/or backups. For a higher-level, more theoretical and more linguistic description of the data model, see here (which is currently very brief, but will be expanded). For programmers who will also use the DDD Django repository, see the `README_code.md` there (yet to be written, for now see `README_datamodel_old.md`).

The document was written for DDD model v1.15 and in line with DDD backup v3.3.

Database technology

The Digital Dictionary Database is a PostgreSQL database. It contains core tables (with prefix "jedro_"), metadata tables (with prefix "metadata_") and internal tables managed by Django and other integrated packages (with prefixes "django_", "auth_", etc.). The core tables contain the Slovene linguistic data, while the metadata tables refer to the core tables and contain data which are not considered part of the language description, but which are needed for central applications (e.g., longer names for dictionaries to display in the database editor).

We define and manage the database via the Django ORM. Partly for this reason, all tables have a single rather than composite primary key (docs). Also, we make use of Django's content types and generic relations (docs), which allow us to associate some simple extra data related to any table without adding lots of new columns or many-to-many tables. However, this means that special care needs to be taken with this data if using the database outside of Django.

Furthermore, for several reasons, some data is more naturally stored in other formats. However, they are still technically part of the SQL database, so that all the data is in one place and so that SQL transactions can encompass changes to this data. They are stored as whole strings in the "extension" table. Currently we have only two such extensions, both in XML format, and we intend

to keep this to a minimum.

This readme focuses on the core data model, which is by far the most complex part of the database.

Core model diagram

MySQL WorkBench diagrams are used to develop and visualise the core of the data model. The project's main Django models.py file is (manually) kept in synch with diagram changes. The latest (v1.15) version of the data model is available here.

The diagram contains several color-coded clusters of tables. For a conceptual explanation of the domain, see here. This readme will provide a more technical explanation and interpretation of these tables and the key relationships between them. Note that the tables with a relatively dark colour shade in the diagram are just basic coding tables (with only id and name), so will not be covered here explicitly, unless they are of particular importance. Also note that every table in this model also has a last_modified timestamp column, but these are not included in the diagram to avoid repetitive clutter.

Model clusters

Lexical units

The main lexical unit table (`LexicalUnit`) is the central table in the database. Lexical units consist of a type (`LexicalUnitType`), a syntactic structure (`SyntacticStructure`) (ref), and one or more parts (`LexicalUnit_Part`). They are also assigned categories (`LexicalUnitCategory`) and can be related to each other (`LexicalUnitRelation`).

As (soon) explained here, there are five types of lexical unit, which fall under two broader categories: independent (`single_lexeme_unit`, `compound`, `phrase`) and dependent (`collocation`, `combination`). For example, "miza" would be a `single_lexeme_unit`, "okrogla miza" a `compound`, and "velika miza" a `collocation`. Independent types are potential headwords with their own entries in dictionaries, while dependent units can be included in the entries of headword units. At the level of the lexical unit tables, this difference is usually irrelevant, but as we will see, the types do impact how associated data in some other tables are interpreted (e.g., senses, resources).

Lexical unit parts correspond roughly to tokens in corpora. Usually these are words, but not always (the 2nd part of "francosko-slovenski slovar" may correspond to the punctuation character `-`). In the data model, `LexicalUnit_Part` connects the lexical unit of the part (`LexicalUnit`), the component of that unit's syntactic structure the part corresponds to (`StructureComponent`), and the form of the

lexeme (`FormEncoding`) of that part. For instance, the first (of two) parts of "okrogla miza" connect the lexical unit "okrogla miza" with the first component of the common adjective-noun syntactic structure (ref) and the orthographic form of the appropriate form (feminine singular nominative) of "okrogel" (ref).

A lexical unit is uniquely determined by its type, structure and sequence of parts. Therefore, we cannot have multiple units which have the same combination of these properties, but we can have multiple lexical units which only partially match. For example, we may have two units "švicarski nož" (a `compound` and a `phrase`), or two noun `single_lexeme_units` for two forms of the same lexeme ("oblast" and "oblasti").

Lexical units are further described by a lexicographic category (`LexicalUnitCategory`). These are somewhat akin to the categories of lexemes (`Category`) ([ref][#bkmrk-word-forms]), and may duplicate the same information for single_unit_lexemes. However, they are needed at this level for lexical units with multiple parts to describe a multiword unit's category as a whole. For instance, "okrogla miza" could be assigned a category of "noun phrase". Also, they can be useful to assign lexical units which technically have multiple parts but conceptually have one to a simple category (e.g., "covid-19" as a noun).

`LexicalUnitRelations` relate two lexical units with a particular relation type. The interpretation is that for a given combination (`from_lexical_unit`, `to_lexical_unit`, `type`), `to_lexical_unit` is a `type` for `from_lexical_unit`. If the relation is symmetric, it is stored twice, once in each direction. (These conventions also apply for the other relation tables.)

Senses

While lexical units may be the most central unit in the data model, senses (`Sense`) are probably the level to which the most data is attached. Lexical units have 1 or more senses, and each sense belongs to a particular lexical unit. Senses can have definitions (`Definition`), they contain parts (`Sense_Part`) and they can be related in various ways (`SenseRelation`). Certain relations can be grouped into predefined clusters (`SemanticClusterType`). We can also store measures of sense occurrences in corpora (`Sense_Measure`). And if we don't know which of several senses is appropriate for some data, we can group alternatives (`SenseCandidate`).

Definitions are string descriptions of a sense. They are only used for independent lexical units, for which they are the main aid in identifying senses for lexicographers and users. Definitions can be of different types, among which `indicator` is the most common and important.

Each lexical unit has 1 or more senses with a particular (possibly null) position. However, their interpretation depends on whether the lexical unit is dependent or independent (ref). For independent lexical units, `Senses` with a non-null position are "real" senses, normally equipped with further lexicographic data such as definitions or labels. The positions determine the order of a lexical unit's senses, normally via lexicographers' explicit decisions. But every independent lexical unit is also given a so-called "dummy" sense, which has null position and is used when we want to

associate sense-level data with a lexical unit, but we don't yet know under which sense (which is a common situation because of the challenging nature of automatic semantic categorisation etc.). In addition, if we know that some data corresponds to one of a particular proper subset of a lexical unit's senses, we can also have a sense with null position and candidate pairings (`SenseCandidate`), which relate particular senses (as `candidate_sense`) to that sense (`potential_sense`). However, this sense candidate support has not yet been put to use.

In (lexicographic) theory, dependent lexical units do not have senses, as indeed the main reason they are "dependent" is that their meanings derive somehow from the meanings of their parts (compare "okrogla miza" and "velika miza"). But from a technical point of view, since many kinds of data that are attached to senses (e.g., translations, examples, labels) are relevant for both independent and dependent units, dependent lexical units do have senses as well. For dependent lexical units, all senses have null positions (their ordering in particular contexts is determined by calculable criteria), and we do not anticipate to need sense candidates. However, a dependent lexical unit can still have multiple senses, such as the literal and figurative meanings of the collocation "svinjski jezik" (which will will have different translations, for example). Different senses of the same dependent lexical unit are distinguished by their parts (`SensePart`) and dependency relations (`SenseRelation`) (see below).

Sense parts (`SensePart`) serve two functions, identified by two different types. `within_other` parts indicate which lexical unit parts of a dependent unit correspond to the sense of a particular independent unit. For instance, the compound "okrogla miza" ("miza") is found in the 2nd and 3rd parts of the collocation "organizirati okroglo mizo". (The reason that sense parts refer to senses of independent units rather than the lexical units themselves is to make it easier to handle example tokens (ref).) `within_self` parts, on the other hand, allow us to indicate the `role` of the part in the sense (which is null for `within_other` parts). The roles are defined, managed and assigned by lexicographers. In `within_self` parts, we are always connecting lexical unit parts of a lexical unit with that lexical unit's own sense, which is redundant, but it does simplify our data model as it prevents the need for creation of two similar tables.

Sense relations (`SenseRelation`) relate pairs of senses with a certain relation type. Senses of two independent lexical units can be related with classic semantic relations (e.g. `synonym`, relating a particular sense of "mali" with a particular sense of "majhen"). These relations always go in pairs; for example, if "avto" is a hyponym for "vozilo", then "vozilo" is a hypernym for "avto". In addition, a `subsense` relation, which indicates that one sense (`to_sense`) can be understood to be a subsense of another (`from_sense`). Basic statistical data (e.g., degree of synonymity) can also be stored (`SenseRelation_Measure`).

There is also a special relation type (`dependency`) which relates a dependent unit's sense (`to_sense`) with an independent unit's sense (`from_sense`). For example, the literal sense of "svinjski jezik" can be related to the physical senses of "svinjski" and "jezik", while its metaphorical sense can be related to more abstract senses of "svinjski" and "jezik". We can also have a sense of "svinjski jezik" which is not related to any independent unit senses, which would be the "dummy" sense for the dependent lexical unit. Therefore, sense relations between senses of independent lexical units give additional information about senses, while dependency sense relations help define a dependent sense.

Dependent unit senses can also be organised in clusters under the independent senses which they are related to. A set of cluster types (`SemanticClusterType`) is pre-defined for each lexical unit category (`LexicalUnitCategory`). Each dependency sense relation can be assigned (`SenseRelationClusterType`) to one of the cluster types of the independent unit's category. For example, if the "noun" category has a "what material?" cluster type, then the "lesena miza"-"miza" relation would be assigned to this category for the appropriate sense of the lexical unit "miza".

Sense measures (`Sense_Measure`) record basic statistical measure values for a sense in a particular corpus. For instance, we would use this table to record that the physical sense of "svinjski jezik" occurs in a particular corpus 157 times. If we are dealing with a corpus which has not been semantically disambiguated, we can use the lexical unit's dummy sense (i.e., the position-less sense of an independent unit or the relation-less sense of a dependent unit).

Word forms

Slovene is a highly inflectional language, where words have many forms with different sets of features, so the data model includes a hierarchy of tables for morphological data. From top to bottom, there are word grammatical categories (`Category`), form-independent lexemes of particular categories (`Lexeme`), the set of morphosyntactic descriptions (MSDs) for each lexeme (`WordForm`), concrete forms for such combinations (`FormRepresentation`) and actual string representations of those concrete forms (`FormEncoding`). Word forms have a hierarchy of form representations of different types, encoded as relations (`FormRepresentationRelation`). We can also store basic form representation corpus statistics (`FormRepresentation_Measure`), and classify form representations by their paradigm patterns (`FormRepresentation_Pattern`). Finally, lexemes also have canonical form representations for each type (`Lemma_FormRepresentation`).

Lexemes (`Lexeme`) represent a word (or punctuation) consisting of a lemma (the basic or dictionary form of the word) (e.g., "miza"), a category (e.g, "noun", "preposition", "punctuation") and a set of category-dependent lexeme-level MSD (see below) features (e.g., noun gender) (ref). This combination almost uniquely determines a lexeme, so we can have two different lexemes with the same lemma (e.g., "dolg"), or even with the same lemma and category (e.g., "klop"), but normally not with the same lemma, category and lexeme-level MSD features. The exception is if we have differences in non-orthographic form representations (e.g., lesen (accentuation="lesén") and lesen(accentuation="lésen"). When these are encountered during matching and we have to make a choice automatically, we can exclude the lexemes marked with the feature "lexeme_homonym_secondary".

For a given lexeme, word forms (`WordForm`) are in effect abstract nodes for grouping together forms under particular MSDs. MSDs (`Msd`) are linguistic codes which encode a particular combination of morphosyntactic features morphosyntactic description. For instance, Slovene nouns typically have 18 word forms (6 cases x 3 numbers), so there are 18 Slovene MSDs for nouns. Each Msd contains such a code, along with the features that are specific to particular forms (e.g., adjective gender), but the word category and lexeme-level features are not stored at this level, as word forms inherit them from their lexemes.

For each abstract word form, there is a hierarchy of form representations (`FormRepresentation`). We currently have three different types of form representations: `orthography` (e.g., "dekan"), `accentuation` (e.g., "dekàn") and `pronunciation` (e.g., "dɛˈkan"). Accentuation representations fall under particular orthography representations, and pronunciation representations fall under particular accentuation representations (e.g., "dɛˈkan" falls under "dekàn", not "dekán", although they are all form representations corresponding to the MSD "Ncmsn"). These inter-type relationships are encoded as relations (`FormRepresentationRelation`). In case there are multiple representations of the same type for a given form, `norm_status` can be used to indicate the representation's relative status (e.g., "non-standard", "variant").

The actual string representations of form representations are stored as form encodings (`FormEncoding`). This is a separate level, because there can be multiple encodings for the same representation using different encoding scripts. For instance, pronunciations can be encoded using SAMPA or IPA, and in some languages even orthographic forms are commonly written with different scripts (e.g., Cyrillic and Latin for Serbian).

As for senses, we can store basic corpus statistics at the level of form representations (`FormRepresentation_Measure`). For instance, this table can record that the single genitive variant "Shakespeareja" of the masculine lexeme "Shakespeare" occurs 123 times in Gigafida 2.0.

Also, form representations tend to follow certain paradigms (as typically described in grammar books). These are managed by lexicographers and represented with pattern codes (`FormPattern`). Individual form representations can then be assigned to particular patterns (`FormRepresentation_Pattern`).

Finally, a lexeme's lemma can be explicitly associated with a subset of its form representations (`Lemma_FormRepresentation`). This normally consists of all the form representations which fall under a particular abstract word form, which is usually determined by the lexeme's category. For example, for noun lexemes, this would be the representations falling under the singular nominative word form. The lexeme's `lemma` should match one of the lexeme's orthography lemma representations.

Syntactic structures

Syntactic structures describe the structure of the canonical forms of lexical units. Each syntactic structure (`SyntacticStructure`) defines a sequence of components (`StructureComponent`), their properties, and dependencies between them. Structures can also be related to each other (`StructureRelation`). Each lexical unit falls under a particular syntactic structure. However, most of the details of syntactic structures are not stored in the SQL database, but rather in a related XML extension file (static/extensions/structures.xml). There are several reasons for this (see wiki). The format and contents of this XML extension will not be covered here.

Structures (`SyntacticStructure`) have only an id, which serves primarily to connect the SQL core and XML extension. New lexical units are normally assigned to particular syntactic structures with a dedicated pipeline. The pipeline uses a standard parser (CLASSLA) together with scripts which match the lexical unit's sequence of parts to a syntactic structure, and creates a new XML structure

if necessary. Such new structures are then added to the SQL database separately.

While most of the details of syntactic structures are kept in the XML, we do also register the components in SQL (`StructureComponent`). The main reason for this is so we can efficiently access the position (`index`) of the component within the structure, which is relevant when working with `LexicalUnitParts` (ref).

We can associate structures with each other as relations (`StructureRelation`). For instance, lexicographers may want to explicitly relate two structures which are similar except that the verb is reflexive in one structure but not in the other (e.g., consider lexical units "umivati roke" in "umivati si roke").

Corpus examples

Senses of lexical units can be associated with corpus text to demonstrate real usage. Corpora (`Corpus`) are registered in the database. Examples (`Example`) always come from a particular corpus and are comprised of sentences (`ExampleSentence`). A single example can apply to different lexical units in particular senses (`Sense_Example`), and we track the tokens of those lexical units within the examples (`SenseExampleToken`). Examples can be related to each other (`ExampleRelation`).

Corpora (`Corpus`) are external resources of parsed text or speech and identified with a name and version (e.g., Gigafida 2.0).

Examples (`Example`) are a sequence of sentences from a corpus that have been chosen to exemplify one or more lexical units. In most cases, they have only one sentence, but sometimes consist of more, when more context is needed.

The sentences of an example (`ExampleSentence`) have an id internal to the corpus, and a position within the example. With the use of an external API, the id can be used to fetch the structured sentence from the corpus in TEI format. Basic statistical data (e.g., quality of example) can also be stored (`ExampleSentence_Measure`).

Senses of lexical units can be associated with a particular example (`Sense_Example`). The same example can be used for different lexical units (e.g., "Organiziral je okroglo mizo." could be an example for senses of "organizirati", "okrogla miza", "organizirati okroglo mizo", etc.).

We also track which tokens of an example represent the lexical unit (`SenseExampleToken`), which is useful when visualising examples, such as marking the lexical unit in bold. For instance, if "Organiziral je okroglo mizo." is used as an example for "okrogla miza", then in this table we would note positions 3 and 4. However, for dependent lexical units (ref), we may also want to differentiate between one of its independent lexical units and the rest. For instance, if "Organiziral je okroglo mizo." is used as an example of "organizirati okroglo mizo" and we are considering it as a collocation for "okrogla miza", then we might want to put, say, "okroglo mizo" in bold and "organizirati" in italic. For this reason, the table also includes a `SensePart` (ref): if the SensePart is of

type `within_other`, then we can use it to make this distinction.

Sense translations

The data model supports storage of translations from Slovene to other languages (`Language`) for senses (`Sense`) and examples (`Sense_Example`) and may be in the form of an ordinary translation (`Translation`) and/or explanation (`Explanation`). If the translations come from external sources (`ExternalSource`), such as monolingual dictionaries of other languages, they can be associated with translations (`Translation_ExternalSource`) along with an external id.

Since translations are used for both senses and examples, a more abstract table is also used (`Translation`). A translation may be empty, in which case it should have at least one associated explanation.

Explanations (`Explanation`) are alteratives to translations, and are normally a longer description. They do not need to be in the same language as the `Translation` (this may depend, for example, on the target users).

Translations are stored for senses (`Sense_Translation`) and examples (`SenseExample_Translation`). Note that translations are not symmetric. For senses, the translation will be analogous to the string of a lexical unit in the other language (and not a particular sense of that unit). For examples, the text of the translation is stored directly in the database and the lexical unit is not marked (ref).

Sense frames

Frames provide a formal description of a verb's semantic arguments. Frames (`Frame`) have components (`FrameComponent`). The same abstract frame can be used by senses of different verbs (`Sense_Frame`), for which components may have specific subroles (`SenseFrame_Component`). As this part of the data model has not yet been used, it may well undergo further development.

In the model, frames (`Frame`) themselves are abstract elements with only ids. In addition to providing foreign keys for related tables, these ids will also be used in a new xml extension for semantic frames (analogous to ref).

Each frame has a set of frame components (`FrameComponent`). The components are of different types corresponding to semantic roles (e.g., agent, experiencer, goal).

Senses of independent lexical units can be assigned to particular frames (`Sense_Frame`). For example, a sense of `dati` might be associated with a frame which has an agent component for the giver, a patient component for the object given and a recipient component for the recipient.

For particular verbs, frame components take on more specific roles than prescribed by their component type (`SenseFrame_Component`). For instance, while agent components may generally

include any kind of animate objects, a verb like "plavati" is restricted to humans and animals.

Resource connections

In addition to storing lexical units and their diverse associated data, the data model also supports the means to group (roughly speaking) subsets of this data for particular purposes (e.g., a Slovene-Hungarian dictionary portal) and assign them statuses in that context. There are registry tables for resources (`Resource`) and statuses (`Status`), and we can assign headword lexical units to resources (`LexicalUnit_Status`) for valid combinations (`Resource_Status`), as well as specifying relevant translation languages (`Resource_Language`). We can also specify if certain data under headwords should be included in a resource and with what status (`ResourceRelevance`).

The resource table (`Resource`) just registers resources with a short name or acronym (e.g., "vsms" for the Slovene-Hungarian dictionary). Each resource is typically associated with a relatively large project or particular perspective on the database (model and/or data), and lexicographers may want various imports or exports specific to that resource. There will often also be a particular portal for a particular resource (VSMS), for which a simplified resource-specific database is normally generated from the central database. If a resource is a bilingual or multilingual dictionary, then it is assumed that the source language is Slovene, and the target translation languages are explicitly stored (`Resource_Language`) (e.g., Hungarian and Serbian for a dictionary resource with translations of Slovene units in Hungarian and Serbian). There is also a special "ddd" resource, which represents a kind of meta-resource, as it includes all the data (rather than just subsets as determined by lexicographers). For example, whenever a new collocation is created, it is automatically included in this resource (see `ResourceRelevance` explanation below).

The status table (`Status`) registers the global set of string statuses that are potentially available to use for resource headwords (e.g., "manually-checked"). The actual statuses available for a particular resource are then a subset of that (`Resource_Status`).

Independent lexical units can be "included" in a resource by assigning them a status of that resource (`LexicalUnit_Status`). Doing so effectively makes them headwords for the resource. For instance, if "miza" is assigned a particular status (e.g., "automatic") associated with the Sloleks resource, then lexicographers will expect that "miza" will be a headword in the (generated) Sloleks portal, perhaps marked in a particular way to signal that particular status. Note that dependent lexical units cannot be assigned to a resource in this way, because by definition they cannot be headwords but rather fall under them.

In order to specify if and how data subordinate to headwords should be included for particular resources, a special Django feature is used (generic relations, which allows us to have one table (`ResourceRelevance`), rather than a separate one for each type of subordinate data, to specify resource relevance. The content type (`content_type_id`) identifies the appropriate table and the object's id (`object_id`) specifies its id within that table. Since some types of objects (e.g., dependent lexical units) could fall under different headwords, `headword_id` is used to explicitly specify the headword (e.g., we may want to include the collocation "velika miza" under "miza" but not under

"velik" for a particular resource). The `inclusion_id` and `status_id` columns specify whether the data should be included and with with what status, respectively.

However, in order to avoid the need for exhaustively adding and updating a `ResourceRelevance` row for every single piece of subordinate data under every single headword in every single resource, a set of agreed upon rules and defaults is applied. First, only specific preestablished kinds of data can be selectively included in resources - at present these are headword senses, dependent unit senses (which in practice means collocations and combinations), and sense examples. Second, the default is that headword senses are included (`ResourceRelevanceInclusion`:`include`), while dependent unit senses and sense examples are excluded (`ResourceRelevanceInclusion`:`exclude`). Third, it is assumed that a default status is defined for each resource (note that these statuses are different than the headword-levels ones in `Resource_Status`). Under these assumptions, resource relevances only need to be defined for data if it is of one of the specified types, and its inclusion and/or status are not the defaults. If the columns contain null or the default for both columns, then it is the same (in the business logic) as if the row is not included.

Generic features

In order to enable associating objects with particular features without promoting them to columns in their tables (which may or may not be relevant for all objects in the table), the data model also provides some tables for more generic purposes. Features (`Feature`) can be defined which take on a set of values (`FeatureValue`) and are grouped into categories (`FeatureCategory`). Values can be associated with objects (`Object_Feature`) and enter into relations (`FeatureValueRelation`). Also, objects can be ordered for the sense under which they belong (`SenseObjectOrder`). Finally, playing technically separate but conceptually similar function to features, the `Measure` table registers statistical measures for data.

Every feature (`Feature`) has a name and belongs to a category (`FeatureCategory`), the combination of which must be unique. Feature categories serve to group related features. In practice, we've used categories with names that match the table that they are used with (e.g., `sense_translation` for features which are only used with `Sense_Translations`), or the generic category `general` if a feature is used with objects from multiple tables.

Feature values (`FeatureValue`) list all the allowed values (as strings) of a feature. The model does not distinguish between theoretically close-ended features (e.g., "gender") and open-ended features (e.g., "latin_name"); for the latter, extra feature values are just created as needed.

While features with their values are ultimately more or less equivalent to basic name-value pairs, they can also be related to each other if needed. A particular case of this is with labels, where there are two hierarchies of features: `label_type` and `label_value`. For instance, the `label_type` feature has a value "domain", which is related to a subset of the `label_value` feature (e.g., "zgodovina", "kemija", "organska kemija"), and these values have hierarchical relations (e.g., "kemija" -> "organska kemija").

Using the same Django generic relation mechanism as `ResourceRelevance` (ref), objects of *any* table in the core data model can then be associated with one or more values of one or more features (`Object_Feature`). This is enabled with a combination of two columns: `content_type_id` and `object_id`. `content_type_id` refers to django's `django_content_type` table, where ids (`id`) are associated with table names (`model`), while the `object_id` column specifies the id in that table. For example, if an `Object_Feature` has content_type_id=18 and object_id=71, and the `django_content_type` table has model="sense" for id=18, then the `Object_Feature` applies for the `Sense` with id=71. Note that an object can also have multiple feature values, even (though rare) for the same feature.

In a similar fashion, the lexicographically relevant order of objects subordinate to the same sense can be specified using a similar table which also uses the generic relation mechanism (`SenseObjectOrder`). The orders are interpreted in the context of a particular table. For example, we can specify the relative order of a sense's individual features, including its labels, semantic types and other features, but these are all in one ordering list, since they are in the same table (`Object_Feature`). Objects with no explicit order are interpreted as being in random order after the ordered ones.

Finally, there is a separate registry table of measures (`Measure`), which can be used to record basic statistical information for different kinds of data in particular corpora. The model supports this for senses (`Sense_Measure`), form representations (`FormRepresentation_Measure`), example sentences (`ExampleSentence_Measure`) and sense relations (`SenseRelation_Measure`).

Other formats

A special table (`Extension`) is used for data in other formats. The columns specify a unique `name`, `format` (currently only XML is used), `string` with the string representation of the data, and `hash` for that string representation. For example, one row in our current database contains the details of the definitions of all syntactic structures, with @id attributes in synch with `SyntacticStructure` ids. The hashes are derived using SHA512, which allows for more efficient checks if data has changed.

These extensions allow for more flexibility in data representation and prevent a proliferation of special-purpose tables and columns, but we try to keep them to a minimum so that the vast majority of the database can be queried and manipulated via standard Django and SQL operations.

REST API

Public REST API for accessing the database.

API design

Principles of the API design:

1. All documented routes should be appended to https://blisk.ijs.si/api/.
2. All the routes are available as POST calls, even if they do not result in changes in the database, because:
   - some routes will have non-trivial input parameters (structured data, arbitrary strings), which are difficult and clunky to encode as path parameters, and expecting request body parameters in GET calls can be problematic and misleading
   - we can have short clear URLS for all routes, and there are limits on URL length in some contexts.
3. Some routes also have a GET counterpart, which behave the same way as the POST call but do not allow for response body parameters (default values are used instead).
4. All request parameters are provided as JSON request body parameters, except for the object's id, which is used to identify a given object and provided as an obligatory path parameter for certain types of calls (e.g., retrieve).
5. The following HTTP response codes are used:
   - **200**: for most successful requests
   - **201**: for successful get-or-create requests where no matching object was found and a new one was created
   - **400**: an error occurred due to invalid or unexpected request parameters or combinations
   - **401**: authorisation denied (suitable credentials are needed for routes which write to the database)
   - **404**: objects were not found for the value (usually id) provided
   - **501**: the specifications for this route are designed but it has not yet been implemented
6. Each route falls under a particular type of operation identified with a particular verb as the first part of the route. The verbs include:
   - **retrieve**: return data for a given object
   - **search**: return all the objects which match the set of search parameters
   - **get-or-create**: get the object matching the parameters provided, creating one if necessary, along with any other missing objects it depends on
   - **update**: update the properties of a given object based on the parameters provided
   - **delete**: delete a given object
   - **attach**: attach the given object to a particular resource, if not yet attached
   - **detach**: detach the given object from a particular resource, if attached
   - **process**: process the input data with an appropriate independent tool (e.g., the CLASSLA NLP library)

7. If the operation verb has a "-batch" suffix, it differs from its non-batch counterpart as follows:
    - users can make 1 API call instead of N API calls for N items
    - the input data should be a list, with each element in the format expected by the non-batch route
    - the output data is a list, with each element corresponding to the element at the same position in the input, where each element has three fields:
        - status: the HTTP response code that would be used if the element was processed in a non-batch call
        - message: a message describing the results of the operation (e.g., whether an object was found or created, or the cause of the warning or error)
        - data: the output data (for successful calls), in the same format as non-batch output
8. Routes which do not change data in the database (retrieve, search, process) are publicly available. Routes which may result in changes in the database (get-or-create, update, delete, attach, detach) require authentication credentials.

REST API

API routes

The API is being designed and developed, with priority on current needs. Specifications are available in redoc (which is better formatted visually) and swagger (which allows you to try the API via the interface).

Here is a list of the current routes (last update: 06.12.2022). All routes are available with POST, while some of them also have GET or batch POST alternatives (ref). The routes that are not read-only have restricted access.

Route	Read-only	Description
/search/lexical-unit/	yes	search for lexical units based on their properties and parts
/retrieve/lexical-unit/	yes	get a lexical unit's basic data
/get-or-create/lexical-unit/	no	get or create a lexical unit based on properties and components
/search/lexeme/	yes	search for lexemes
/retrieve/lexeme/	yes	get a lexeme's data
/get-or-create/lexeme/	no	get or create a lexeme based on defining properties
/retrieve/lexical-unit-lexemes/	yes	get the lexical unit's component lexemes
/search/category/	yes	search for a lexeme's category (part of speech) by string
/search/form/	yes	search for word forms by string
/search/sense/	yes	search for senses
/retrieve/lexical-unit-senses/	yes	get the senses of a lexical unit
/retrieve/lexical-unit-sense-relations/	yes	get the sense relations of a lexical unit's senses
/retrieve/lexical-unit-collocations/	yes	get the collocations of a lexical unit
/retrieve/lexical-unit-translations/	yes	get the translations of a lexical unit
/retrieve/lexical-unit-sense-examples/	yes	get corpus examples for the senses of a lexical unit

Route	Read-only	Description
/get-or-create/resource/	no	get or create a dictionary or other resource
/search/resource/	yes	search or list resources available
/attach/lexical-unit/	no	attach a lexical unit to a resource
/detach/lexical-unit/	no	detach a lexical unit from a resource
/search/syntactic-structure/	yes	get the XML definitions of syntactic structures
/process/string-to-tokens/	yes	parse a Slovene string to get a list of tokens

API implementation

The public API is being implemented using the Django REST Framework and APIViews in particular. It is part of the Python codebase, Django project and Git repository that is used to manage the database in general. We are striving to keep the business logic and API route definitions in separate modules, so that different APIs (e.g., editor API, internal API) can use the same utils module.

Most of the logic and processing of the API is internal. However, there are a few aspects that rely on other tools, such as Slovene string parsing and fetching of corpus examples.

API use cases

In addition to providing general public access to the database, the REST API can also be used to integrate data and services with external organisations in a coordinated, structured and systematic way. Two current examples of this are integration with terminology portals and speech technologies, both of which use a mix of public (read-only) and restricted (read-write) routes of the API.

Terminology Portal

One of the main parts of the Development of Slovene in a Digital Environment is a terminology portal that will feature various terminological resources and offer an openly accessible tool for term extraction from specialized corpora, as well as the server infrastructure needed to create new terminological resources. The main components of the portal include a search engine for all integrated resources and a terminology resource editor, and the resources are designed to be easily integrated with other language tools and services, including the Digital Dictionary Database.

As such, the portal uses API routes to register its dictionaries in the database, search and create terms, attach/detach them to/from the dictionaries, and fetch their forms and statuses. The API supports this as follows (see the route links for full examples):

- Register the dictionary as a resource in the database using /get-or-create/resource/, providing a code name for the dictionary (e.g., `"slm"`) as input. The API will return the resource's ID (e.g., `87`), first creating it if it does not yet exist.
- Get IDs of terms in the database, creating them if necessary, using /get-or-create/lexical-unit/. Input can be either the term's raw string (e.g., `"okrogla miza"`), or its pre-analysed sequence of tokens, with each token represented with corpus-style data (e.g., `[{"lemma":"okrogel", "msd":"Ppnzei", "form":"okrogel"}, {"lemma":"miza", "msd":"Sozei", "form":"miza"}]`). If a raw string is provided, the API uses a standard tool to get a sequence of tokens itself. Either way, it then checks if a matching lexical unit exists in the database, creates one if necessary, and returns its basic data, including its ID (e.g., `54321`). If many terms need processing, this can be done by using the /get-or-create-batch/lexical-unit/ call instead and providing a list of inputs.
- Get the word parts and their forms with statuses for a specific term, by using /retrieve/lexical-unit-lexemes/. Input would be the term's ID (e.g., `54321`) and specifying that form statuses and all form types are also requested (e.g., `"extra-data":["status-form-types", "forms-orthography", "forms-accentuation", "forms-pronunciation"]`). The output then a list, with each element is one of the term's word constituents, represented with both its basic

data (such as id, lemma, part of speech, basic word-level features) and the extra requested data (the list of all the forms of all the types for the word and aggregated statuses for each type).

- Search for term candidates in the datases, using /search/lexical-unit/. This has similarities to /get-or-create/lexical-unit but differs in a few key ways. First, it does not create a lexical unit if no match exists, and thus does not require authentification, so less central components of the portal can also make use of it. Second, it does not require complete data in the input (e.g., perhaps only one or two of lemma/msd/form are specified for one or more of the term's components), making the search more flexible and potentially returning multiple matches (e.g., {"lemma":"klop"}).
- Attach the lexical unit to a resource, using /attach/lexical-unit/. The input would be the IDs of the term as a lexical unit (e.g., `54321`) and dictionary as a resource (e.g., `87`). This would then connect the two in the database.
- Detach the lexical unit from a resource, using /detach/lexical-unit/(https://blisk.ijs.si/api/redoc/#tag/detach). The input would be the IDs of the term as a lexical unit (e.g., `54321`) and dictionary as a resource (e.g., `87`). This would then remove the term from the resource in the database, without deleting the term from the database in general.

Speech technologies

The project Tolmač (Eng. Interpreter) is focused on developing of a system for automatically translating lectures from Slovene to other languages, coordinated at the Faculty of Computer and Information Science at the University of Ljubljana, in close collaboration with the Centre for Language Resources and Technologies. The results of the project will be important for a wide range of people: real-time translations will make it easier for foreign students to follow lectures in Slovene, automatic subtitles will help people will hearing loss, and lecture excerpts and recordings will be accessible at a dedicated website. The speech technologies underlying the system rely on search and retrieval of both orthographic and pronunciation word forms of Slovene words.

To that end, the system can use API routes to preprocess text, search for different kinds of word forms, retrieve the forms of word and create new words along with their forms. The API supports this as follows:

- Parse a piece of Slovene text to get a sequence of tokens using /process-string-to-tokens.

  The API runs the standard CLASSLA parser with default parameters and returns a list of tokens in CoNLL-U format, with each token including a lemma (e.g., `"miza"`), MSD (`"Sozmm"`) and form (e.g., `"mizah"`). Thus this API call does not interact with the database, but serves as a handy wrapper for CLASSLA, so the user does not need to install it themselves.
- Search for a word form in the database using /search/form/, by providing a type (e.g., `"orthography"`) and a string (e.g., `"mizah"`). The output is a list of matching forms, along with basic associated data such as lexeme ID (e.g., `123`), lemma (e.g., `"miza"`) and JOS-system MSD (e.g., `"Sozdm"`). Associated pronunciations for all matching forms are

included if requested (e.g., `"extra-data":["forms-pronunciation"]`).

- Get all the forms of a given lexeme using /retrieve/lexeme/, using the lexeme's ID as input. To get all the orthography and pronunciation forms of the lexeme, specify in the input (e.g., `"extra-data":["forms-orthography", "forms-pronunciation"]`).
- Create (if it does not yet exist) a lexeme in the database using /get-or-create/lexeme/. Input consists of a lemma (e.g., `"miza"`) and MSD (e.g., `"Sozmm"`). The MSD can be any appropriate MSD for the lexeme, not necessarily the MSD of the lemma itself, since only the lexeme-level parts of the lemma (e.g., `"Soz"`) will be considered. The API calls the Inflector tool, which generates full paradigms of different kinds of forms (orthography, accentuation, pronunciation), and then saves the new lexeme with its forms in the database. However, if a lexeme already exists in the database which matches the database, no duplicate lexeme (along with forms) is created and the existing lexeme is returned.