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Research Article

The future of German MeSH: a new semi-automatic translation process and new services for search and annotation

Die Zukunft der Deutschen MeSH: Ein neuer semi-automatischer Übersetzungsprozess und neue Services für Suche und Annotation

Abstract

The Medical Subject Headings (MeSH) thesaurus is developed and supported by the National Library of Medicine (NLM). Whereas the main purpose of MeSH is the indexing, cataloging and searching of biomedical literature, we foresee an increasing role in using this terminology for metadata annotation and concept search of research data. Since NLM terminated translation software and support in 2019, ZB MED has decided to take over. In this paper, we present the development of a new semi-automatic translation process in order to enrich MeSH with German terms. The developed software results in a web-based interface where curators can easily proof and edit the automatically translated terms. An additional view for the senior curator ensures quality control. The bilingual MeSH version is provided by ZB MED in various formats to enable easy reuse. Furthermore, it is included within a ZB MED hosted semantic lookup service (SemLookP). This service is well suited for concept search, providing concept information as well as retrieving subtree entries or equivalent concepts in other terminologies for search expansion via both web interface and API.

Keywords: cataloging, indexing, translation, FAIRdata, metadata annotation, terminology

Zusammenfassung

Der Medical Subject Headings (MeSH) Thesaurus wird durch die National Library of Medicine (NLM) entwickelt. Während MeSH bisher weitestgehend zur Verschlagwortung, Katalogisierung und Suche von biomedizinischer Literatur genutzt wird, erwarten wir eine erweiterte Verwendung der Terminologie für die Metadatenannotation und Suche von Forschungsdaten. Da die NLM 2019 ihre Übersetzungssoftware und den Support eingestellt hat, übernimmt ZB MED diese Aufgabe. In der vorliegenden Arbeit beschreiben wir die Entwicklung einer semi-automatischen Software, um die englische MeSH-Fassung mit deutschen Termen anzureichern. Die entwickelte Software liefert eine webbasierte Oberfläche, die es Kuratoren erleichtert, die automatisch übersetzten Begriffe zu überprüfen und zu überarbeiten. Eine zusätzliche Ansicht für den leitenden Kurator sichert die Qualitätskontrolle. Um die Nachnutzung zu erleichtern, bietet ZB MED die bilinguale MeSH-Version in verschieden Formaten an. Zudem integrieren wir diese Terminologie in einen von der ZB MED bereitgestellten semantischen Lookup-Service (SemLookP). Dieser Dienst eignet sich gut für die Konzeptsuche und die Bereitstellung von Konzeptinformationen. Zur Erweiterung der Suche können über die Web-Schnittstelle und die API alle Einträge eines Teilbaums oder äquivalente Konzepte in anderen Terminologien abgerufen werden.

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Introduction

In recent years, the amount of electronic data in the biomedical field has increased enormously. This holds true for the huge volume of newly published research data as well as the growth rate of biomedical articles. For literature, cataloging and indexing has a long history to support the retrieval of relevant documents. For biomedical literature databases such as MEDLINE [1] or PubMed [2], the Medical Subject Headings (MeSH) thesaurus is used for indexing, cataloging and search [3]. MeSH is a controlled biomedical vocabulary, provided and annually updated by the National Library of Medicine (NLM) in different file formats (e.g. XML or RDF format) [4]. The terminology contains 29,640 concepts (main headings) and 212,568 synonyms (entry terms) in its English 2020 version. Due to the broad coverage of biomedical areas in MeSH and its high amount of synonyms, it is very well qualified to match search queries from users to MeSH concepts and thereby expanding these queries and returned results. Although it is mainly used for literature searches, an obvious choice is to use MeSH for metadata annotation in additional fields such as biomedical research data. Currently, the reproducibility of research results and reuse of research data is often hampered by the lack of information about the data. This led to the formulation of the FAIR data principles in 2016 [5], which are nowadays universally accepted within the research community. One major principle is the annotation of data with rich metadata from terminology standards. MeSH is well suited to be used for metadata annotation as well as search expansion. Through the mapping of MeSH to Unified Medical Language System (UMLS) codes [6], it can be easily mapped to other medical terminology and therefore is highly interoperable.

In addition to the English MeSH version, MeSH is standardly translated to further languages. A German version was published annually by the German Institute of Medical Documentation and Information (DIMDI) until 2019 [7]. The translation was done by expert curators and supported by a software tool provided by the NLM [8]. The latter also took care of the conversion into a clean XML format. In the beginning of 2020, ZB MED as the national information centre for life sciences took over the responsibility for the German MeSH vocabulary from DIMDI. Since the NLM translation service was terminated in 2019, we developed a semi-automatic system to simplify the translation process which is presented in this paper. Similar workflows have already been implemented for SNOMED CT. Abdoune et al. [9] translated the CORE subset of SNOMED CT into French by implementing a mapping algorithm taking four different French terminologies into account, thereof ICD-10 and MeSH [9].

Hashemian et al. proposed a semi-automatic workflow to translate SNOMED CT making use of both Google Translate and human translations [10]. We are implementing a similar approach but, in addition, develop a user-friendly curation interface.

In the following, we describe this new service that has been setup to support curators and speed up the task of translating new English MeSH terms into German. It consists of an automatic preprocessing step to translate new MeSH terms and a graphical user interface supporting the reviewing and curation work of the subject specialists. Although the service has been developed for German translations of MeSH, it can be easily adapted to other languages or for other terminologies. Furthermore, in this paper, we describe additional services for the MeSH terminology. The terminology is

1. provided as a bilingual version in different formats, such as RDF, and
2. included in a terminology lookup service (SemLookP), hosted by ZB MED.

With the provision of MeSH within our semantic lookup service, we enable the usage of MeSH for metadata annotation as well as search expansion.

Methods

The newly developed translation service consists of the following steps:

1. identification of new English MeSH terms lacking a German translation,
2. automatic translation of those terms to German,
3. independent curation process based on automatic translation,
4. final review process, and
5. publication of bilingual MeSH version.

For steps 3 and 4, we developed a user friendly graphical user interface for the presentation of the translation results as well as supporting functions for editing, correction and search of the correct terms. An overview of the entire process is summarized in Figure 1.

Translation workflow

The automatic translation pipeline is completely built upon Python 3. The first step of the pipeline investigates the difference between the old and the current English MeSH versions. To identify new MeSH concepts, the two files (provided by NLM [4]) are compared and those only occurring in the current version are identified and stored. For every new concept, the unique identifier, the English main headings as well as additional synonyms (=entry terms) are extracted. In a subsequent step, these terms are automatically translated by accessing the DeepL API [11].

The web-based graphical user interface (GUI) presents the results for curation to the user. The GUI is based on the python web framework Flask and provides DataTables, a “plug-in for the jQuery Javascript library” [12]. DataTables directly provides several functionalities, such as sorting, filtering and searching. The program can be accessed via web browser and is therefore independent

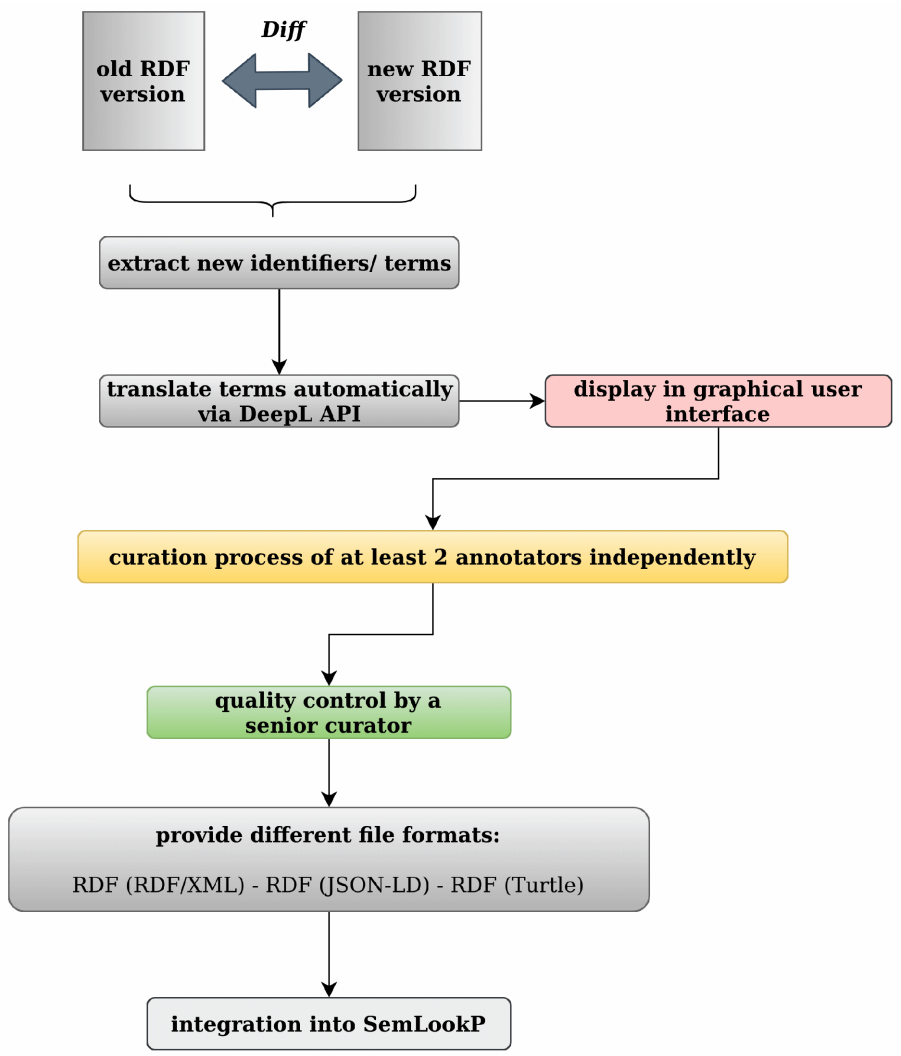

Figure 1: Simplified workflow of MeSH translation software.
In a first step, the new terms are identified. Afterwards, these terms are automatically translated and displayed in the interface. The terms are curated by at least two annotators independently and finally checked by a senior curator. After finishing the translation, the terminology is provided in different formats and integrated into SemLookP.

from the operating system. Also, there is no need for any programming knowledge of the curators. Via the GUI, the unique identifier, the English main headings, its entry terms and all generated translations are provided to the curator. The developed program allows curators to either accept the automatically translated term or to edit it, provide fast overviews and enable direct access to further web resources.

Curation is performed by at least two annotators independently in order to ensure high-quality translations. To ensure consistency with previously translated MeSH terms, we developed annotation guidelines in coordination with DIMDI. For further quality control, the translation has to be reviewed and accepted by a senior curator. In case of unambiguous annotations from both annotators, the senior curator controls random samples as quality check. In case of disagreement between the annotators, the translations are reviewed by the senior curator who takes the final decision. After the senior curator has finished the translation phase, a new MeSH version is created.

The **merged MeSH version** contains all entries of the English MeSH version, all German names from the DIMDI XML version [7] and the newly generated German names and synonyms. The 2020 bilingual MeSH version is made available in different RDF formats (RDF/XML, JSON-LD, Turtle).

Semantic lookup of MeSH

In addition to the publication of the bilingual MeSH version, the terminology is integrated into a semantic lookup service, SemLookP, which is hosted by ZB MED (service publication and corresponding paper in preparation). SemLookP contains a terminology and a mapping service. Both services are developed by the European Bioinformatics Institute (EBI) for lookup of ontologies and are extended to the semantic lookup service by including non-ontological terminologies and their mappings as well. The terminology service is based on the EBI Ontology Lookup Service (OLS) [13]. OLS is a repository for vocabularies (ontologies and terminologies), which provides additional

information for each concept in the vocabulary. In addition to the hosted service from EBI, our service can add multilingual names and synonyms for a concept. Connections between the concepts in different vocabularies are provided by the mapping service which is based on the EBI Ontology Xref Service (OxO) [14]. The OLS functionality allows the user to use the web interface for concept search and concept view. This functionality can also be included into other search applications as widgets. To integrate the concepts from the SemLookP repository into the search query within a third party application, SemLookP provides an API which only needs a simple search string as input that will be mapped to concepts as well as synonyms in the vocabulary repository. As result, it returns FAIR concepts hits or identifiers (IDs). Subsequently, based on the IDs, data annotated with these concepts can be retrieved. Since SemLookP includes the OxO service as well, mapped concepts or IDs from other terminologies included in OxO can be returned in addition to the MeSH concepts. Thereby, data annotated with different terminologies can be easily queried together. In contrast to other known services, like for example BioPortal [15], SemLookP allows bilingual search and can as such be used for the merged MeSH version including English and German terms.

Results

For the development of the semi-automated translation service, we first identified the requirements for the curation interface. By using a first, simple prototype, those requirements were determined by four different curators with backgrounds in life, library and computing sciences. The resulting features are summarized in the first result section. In the second section, we describe the developed web interface. Next, we evaluate the efficiency of the automatic translation process to be able to judge on its usefulness. Finally, we describe our ontology service SemLookP and how the translated MeSH version can be used.

Feature specification for the curation interface

In order to ensure a fast but high-quality translation, the software needs to fulfill several requests.

1. For each English term within the new MeSH entries, an automatic translation should be performed and resulting German translations together with the original English terms should be displayed in a curator interface.
2. Each term needs to be editable and markable as either “open” or “done”. In addition, there should be the possibility to mark those terms where the curator is not (yet) sure about correspondingly.
3. To allow different persons with different roles to use the same web-based software, a user management system needs to be integrated. Thereby, it can be distinguished between different user rights as well as different views for administrator, senior curator and annotator, respectively. Results and curation status have to be stored for every annotator separately to ensure that results do not get lost and that the annotators can directly continue where they finished up the last time.
4. Concerning the annotator view, the terms are needed to be sortable and filterable based on the status described above.
5. The senior curator needs an additional view: it should provide an overview of both results and the possibility to filter for ambiguous annotations.
6. Coloring the entries to differentiate between finished, open or uncertain translations, makes it easier to get a fast overview of the translation status. This is true for both the annotators and the senior curator.
7. To facilitate further research on the correctness of the translated term, direct links with the term in question would fasten up the search. After first annotation rounds, the curators agreed on the search on following free accessible websites and search engines: https://www.icd-code.de/ (ICD-10-GM) for medical concepts, http://www.chemspider.com/ (Chemspider) for chemical entities and https://www.google.com/ (Google) and https://de.wikipedia.org/ (Wikipedia) as general search engines. Further licensed web services should be included at a later stage.

Web curation interface

The resulting view of the curation interface is shown in Figure 2. In the first column, the unique identifier (MeSH ID) is displayed, followed by the original English terms in the second column. This includes the main heading, marked in bold, and if available, entry terms are also shown, each separated by semicolon. In column three, the German translations can be seen. Also in this case, the translated main heading is marked in bold. In the fourth column, the status can be set and the terms can be edited. The link “edit” allows the user to edit each term (main heading and entry terms) individually and to set a corresponding status. For the generation of fast overviews, the terms are differently colored depending on their status. If a term is marked as “done”, it will appear in green, if it is marked as “to be reviewed”, it is shown in red. Once all terms in a row are marked as “done”, the entire row will be displayed in green. All changes made by the curator can be saved by clicking the *save button*. To search a selected term with external, either general or specific search engines, a mouse-over tooltip can be opened and provides direct links to the respective search engines. This function is available for the original English term as well as for the German translations. Upon clicking, a new tab is opened showing the specific search results for the selected term. This is shown in Figure 3. For the senior curator, an additional

id	english_term	german_term	interact
D000079042	**Maze Procedure**; Maze Procedures; Maze Ablation; Ablation, Maze; Maze Ablations; Maze Surgery; Maze Surgeries	Maisverfahren; Irrgarten-Verfahren; Maze-Verfahren; Labyrinth-Verfahren	open to review done Edit
D000079062	**Interpersonal Psychotherapy**	**Interpersonelle Psychotherapie**	open to review done Edit
D000079102	**Empowerment**	**Befähigung**; Ermächtigung; Bemächtigung:	open to review done Edit

Figure 2: Excerpt of annotator interface.
Each term can be marked as open, done (green) or to be reviewed (red). Once all terms in a row are marked as done, the whole row is marked in green. The preferred term is shown in bold; the synonyms are semicolon-separated.

tabular overview is provided. It includes both results of the curators. In this view, if the curators agreed on the same translations, those rows are marked in green. If the main concept differs, the row will be shown in red. In contrast, if only the synonyms are different, the row is marked in orange.
All curators are provided with a user account which allows for parallel working and also ensures that the senior curator is provided with a different overview.

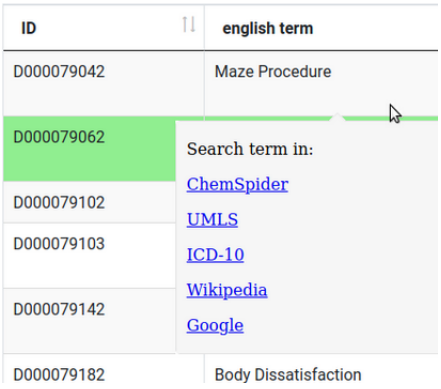

Figure 3: Tooltip to directly search the term with a specific search engine.
With a mouse-over, a tooltip is shown providing links to directly search the term with a chosen search engine.

Annotation statistics and efficiency evaluation

Comparing versions 2019 and 2020, 294 new concepts were added to MeSH. Within these concepts, 1,092 new synonyms exist. All concept names and synonyms were included into the automatic translation process and presented within the curation interface. For all concepts, at least the German main heading was added to the MeSH version. If the system did not propose at least one correct name, further searches based on the provided links were performed to identify an appropriate German main heading. In order to investigate the effectiveness of the automatic translation process, we randomly chose 50 English terms to analyze translation performance and editing efforts. The results are summarized in Table 1.

Out of the 50 terms, 38 translations were considered as being correct, i.e. 76%. An example would be the translation of “famine” (D000079685) into “Hungersnot”. Eight terms (16%) were marked as false and have been edited (i.e. replaced by new terms). An example of a false translation is the term “Gemeindebasierte Krankenversicherung” for the English MeSH term “Community-Based Health Insurance” (D000080051). In the evaluation set, four terms were marked as “unsure” (8%) and ignored in the final MeSH version (e.g. the proposal of the original term “Chromatin Immunoprecipitation Sequencing” (D000081204) as German translation).

Table 1: Efficiency of automatic translation

	Category			Edited/new entries in additional field
	Correct	Wrong	Unsure	
Terms	38	8	4	8

Usage of MeSH within SemLookP

For easy usage of MeSH in different services, the translated MeSH terminology is uploaded into the terminology service of the semantic lookup service SemLookP. Due to the fact that the service can handle multilingual names and synonyms for a concept, it is possible to search for an English or German name of a term and to get suggestions for concepts via the autocompletion functionality of the search field, as shown in Figure 4.

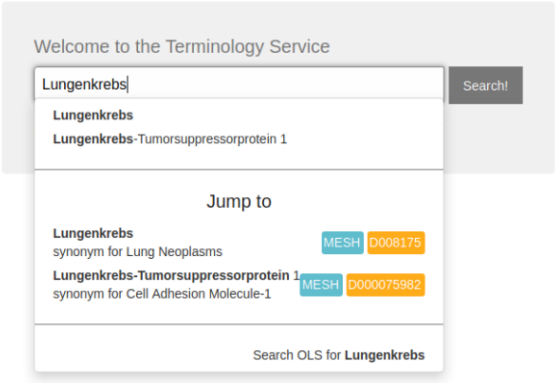

Figure 4: Autocompletion with bilingual information

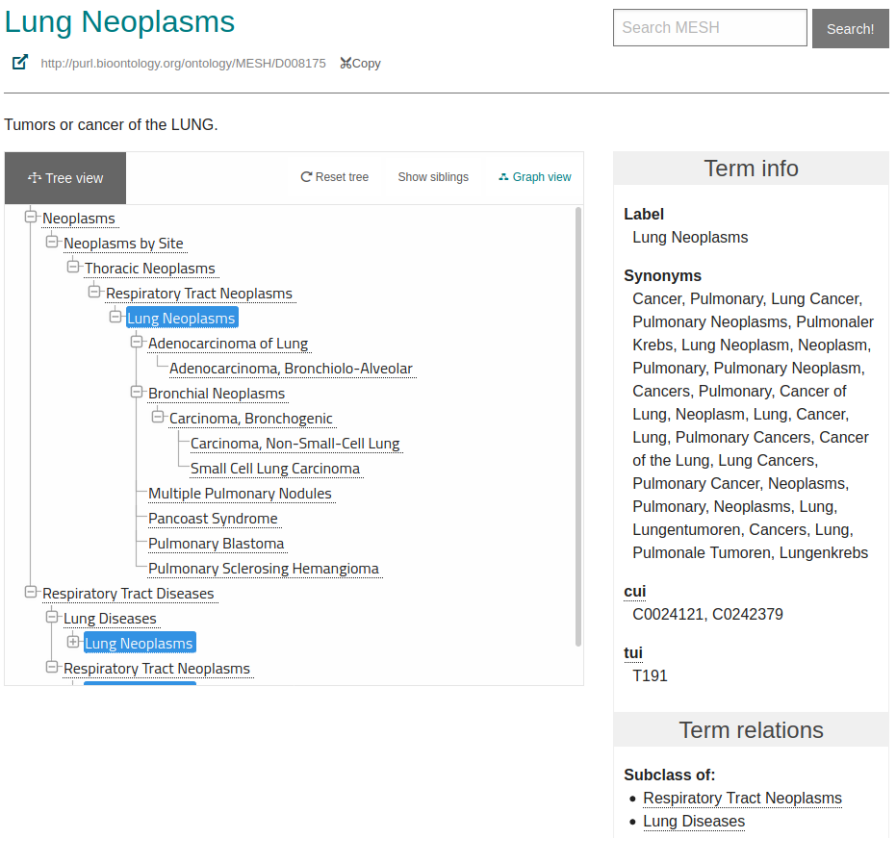

Figure 5: Term information of *Lung Neoplasms* (MeSH:D008175).
Whereas on the left side, the hierarchical information is displayed, on the right side additional information and relations can be seen for the specific term.

Currently, the English language is the default language of the semantic lookup service. Therefore, the terminology service points to the English concept. In the case of the search 'Lungenkrebs', the concept 'Lung Neoplasms' is proposed. In the concept view, the concept is shown in a tree view (Figure 5, left hand side). The tree view shows the hierarchical context of a selected term. The German names *Lungenkrebs*, *Lungentumoren*, *Pulmonaler Krebs* and *Pulmonale Tumoren* are listed in the *Synonyms* paragraph (Figure 5, right hand side).
In addition to the functionality in the front-end, SemLookP can also be used via other RESTful APIs for different purposes such as data annotation or search. One example would be using the RESTful API in order to query for the concepts or IDs of a subgraph of a specific concept within the hierarchy. The command line example query

> *'curl -L https://semanticlookup.zbmed.de/ols/api/ontologies/mesh/hierarchicalDescendants?id=D008175' -H 'Accept: application/json' > mesh_d008175.json'*

outputs the descendants for the term 'Lung Neoplasms'. An excerpt of the result of this query is displayed in Figure 6. With this API functionality, it can be used as a terminology hub for various independent applications using the terminology provided by SemLookP.

Discussion

The MeSH terminology plays a major role in indexing, cataloging and searching of biomedical literature. Since MeSH is used for search expansion within the literature search engine PubMed [2], it is regularly extended with new concepts by NLM [4]. Although the language of most scientific biomedical journals is English, there is a significant number of journal publications in German language. Since the translation of the MeSH terminology is of great importance for indexing and cataloging German literature, ZB MED took over responsibility for German MeSH. In order to support the MeSH curators in translating new MeSH concepts and to reduce the required amount of time, we developed a three step semi-automatic translation approach:

1. automatic translation,
2. expert curation which is supported by a curation interface by two annotators, and
3. quality control by a senior curator.

Currently, this process integrates the commercial tool DeepL. This translation service can be easily exchanged with other translation tools. Despite the translation service, the presented software is freely available and can also be used for MeSH translations into other languages by using other language settings or tools. Similar approaches have been published previously for SNOMED CT. Analog to our approach, Hashemian et al. made use

```
{
  "_embedded" : {
    "terms" : [
      {
        "iri" : "http://purl.bioontology.org/ontology/MESH/D001984",
        "label" : "Bronchial Neoplasms",
        "description" : [
          "Tumors or cancer of the BRONCHI."
        ],
        "annotation" : { },
        "synonyms" : [ ],
        "ontology_name" : "mesh",
        "ontology_prefix" : "MESH",
        "ontology_iri" : "http://purl.bioontology.org/ontology/MESH/",
        "is_obsolete" : false,
        "term_replaced_by" : null,
        "is_defining_ontology" : true,
        "has_children" : true,
        "is_root" : false,
        "short_form" : "D001984",
        "obo_id" : null,
        "in_subset" : null,
        "obo_definition_citation" : null,
        "obo_xref" : null,
        "obo_synonym" : null,
        "is_preferred_root" : false,
        "_links" : { }
      },
      {
        "iri" : "http://purl.bioontology.org/ontology/MESH/D002283",
        "label" : "Carcinoma, Bronchogenic",
        "description" : [
          "Malignant neoplasm arising from the epithelium of the BRONCHI. It represents a large group
        ],
        "annotation" : { },
        "synonyms" : [ ],
        "ontology_name" : "mesh",
        "ontology_prefix" : "MESH",
        "ontology_iri" : "http://purl.bioontology.org/ontology/MESH/",
```


Figure 6: Excerpt of the result file *mesh_d008175.json* of the query for the descendants of *Lung Neoplasms* (MeSH:D008175)

of a translation tool (Google Translate) followed by human translations [10]. However, the authors did not develop a user-friendly interface that allows for parallel curation, but translated based on Microsoft Excel tables. Another solution was developed by Abdoune et al. to translate the CORE subset of SNOMED CT into French. They implemented a mapping algorithm taking four different French terminologies into account, thereof ICD-10 and MeSH [9]. In comparison to our solution, this approach is restricted to the existence of translations in other terminologies. As a consequence, the existing terms have a high probability of being correct, but non-existing terms have to be translated without further support.

The evaluation of the DeepL translations revealed a precision of 76%. In these cases, the curators save time for looking up or writing down the correct translations. The edit function allows the user to correct wrong terms or add new terms. If no correct translation is presented or the user is unsure about the correctness of the translated term, the tooltip directly provides links to relevant search engines. In such a way, the expert curation is supported by the interface. The current workflow setup will be further enhanced in future versions. Considering the translation process, we intend to invite the user community and domain experts to further improve German MeSH. As MeSH covers a broad range of different areas (e.g. chemistry, medicine, biology etc.), domain experts could enhance quality and amount of synonyms. For this purpose, we will extend the current service into a crowdsourcing interface in order to allow proposing synonyms or correct existing ones in a simple way. Thereby, we can optimize MeSH in close contact with the user community and hopefully gather relevant feature requests for both terminology and services.

The bilingual MeSH version provided by ZB MED is now available in different formats: RDF/XML, JSON-LD, Turtle. This facilitates importation into other systems and use in different applications.

A prominent additional use case beyond literature indexing is the usage of MeSH for metadata annotation of research data. Examples of services already using terminologies for metadata annotation are RightField [16], SOCCOMAS [17] or Cedar Workbench [18]. In order to support annotation and search for data in English and German language, the bilingual MeSH version is included into the semantic lookup service (SemLookP). All functions such as autocompletion of German terms and the proposal of the according MeSH concepts work well in the current version. The browser setting for specifying language tags still needs to be implemented resulting in the following restrictions: all concepts in the concept view as well as all concepts in the tree view are visualized with the English names. In the synonym field it is also not possible to view German terms only. In the near future, we aim to modify the data structure of the lookup service to achieve language adaptations. This modification should enable the usage of a specific language tag in a query resulting in language specific output of synonyms. In addition, it would be also possible to switch the preferred language on the web site. In this case, the terminology service would automatically show only German concepts and synonyms in the term overview.

A further enhancement of the provided MeSH version and service relevant to improve interoperability is the integration of mappings from MeSH to other terminologies. We plan to extract mappings from UMLS and other ontologies as well as database resources and include all mappings within the SemLookP mapping service. Examples are mapping of medical terms to ICD-10-GM or SNOMED CT and chemical terms to ATC or ChEBI. Thereby, data annotated with different terminologies can be mapped automatically without further processing or conversion.

Conclusion

The presented work supports the usage of MeSH as an annotation standard in several ways: the semi-automatic translation workflow speeds up the generation of high quality MeSH translations into German. Furthermore, the provision of new machine readable formats as well as the integration within the semantic Lookup service SemLookP extends its usage beyond literature indexing. We foresee the use of this resource for data annotation as well as using the SemLookP functionality to visualize term information within other web applications. In addition, such a service can be employed to search for entire subtrees or to find mapped entry terms of other terminologies. Therefore, semantic search extensions are easily possible. Finally, the freely available software resources can be easily adapted to support the translations of other terminologies and the translation to other languages.

Notes

Availability

Bilingual MeSH 2020 version:
https://semanticlookup.zbmed.de/ols/ontologies/mesh/download
Semantic Lookup Service:
https://semanticlookup.zbmed.de/

Competing interests

The authors declare that they have no competing interests.

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