An algorithm for compiling an electronic multilingual terminological dictionary

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Abstract
Electronic multilingual terminological dictionaries (EMTDs) are dynamic electronic lexicographic resources that offer translation, explanation, and encyclopedic information for terms in various domains of knowledge. They also allow for continuous updating, expansion, and integration with other systems. This paper presents a systematic algorithm for compiling an EMTD that covers five domains (Information Technologies, Linguistics, Accounting and Taxation, Engineering, and Economics) and five languages (English, French, German, Polish, and Russian). The algorithm consists of seven interrelated stages that involve the creation and organization of term registers, the development and testing of an information system, and the setup of the dictionary. The paper discusses the criteria and methods for determining the volume and structure of the EMTD, selecting and ranking the terms, and providing translation equivalents and encyclopedic references in all target languages. The paper demonstrates how the proposed algorithm can facilitate the production of a high-quality EMTD that meets the needs of its users.

1. Introduction

Dictionaries are essential tools in the modern world, as they facilitate cross-cultural professional communication and support the description and understanding of scientific and technical processes [1]. Lexicographers are constantly striving to improve the quality and usability of dictionaries to meet the needs and expectations of their target users. However, traditional printed dictionaries have some limitations, such as limited space, fixed structure, and infrequent updates.

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In the digital era, computer technologies offer new interactive ways to access and present information. Electronic dictionaries can overcome some of the drawbacks of printed dictionaries, such as providing faster and more efficient search functions, integrating various types of information (e.g., thesaurus, encyclopedia, learning programs), allowing data transfer and manipulation, and enabling continuous updating and expansion. Electronic dictionaries are also user-friendly and adaptable to different contexts and purposes. Therefore, electronic dictionaries can enhance the intercultural communication and knowledge exchange among different domains and disciplines.

One of the main functions of electronic dictionaries is to provide translation assistance for terms in various languages [2, 3]. Electronic dictionaries can save time and effort for translators, as they can quickly retrieve the translation equivalents and other relevant information for a given term. Electronic dictionaries can also support multilingual communication and collaboration in various fields of knowledge. Therefore, the development of methods, techniques, and algorithms for compiling electronic dictionaries is of paramount importance.

This paper focuses on one type of electronic dictionary: electronic multilingual terminological dictionary (EMTD). An EMTD is a dynamic electronic lexicographic resource that offers translation, explanation, and encyclopedic information for terms in various domains of knowledge. It also allows for continuous updating, expansion, and integration with other systems. The paper presents a systematic algorithm for compiling an EMTD that covers five domains (Information Technologies, Linguistics, Accounting and Taxation, Engineering, and Economics) and five languages (English, French, German, Polish, and Russian). The paper discusses the criteria and methods for determining the volume and structure of the EMTD, selecting and ranking the terms, and providing translation equivalents and encyclopedic references in all target languages. The paper demonstrates how the proposed algorithm can facilitate the production of a high-quality EMTD that meets the needs of its users.

2. Theoretical background

Research on dictionary peculiarities, its typology, typology of its users, analysis of needs and skills has a long tradition and is presented by the works of Hartmann [4, 5, 6], Hausmann [7, 8, 9], Kosem et al. [10], Leffa [11, 12], Nesi [13, 14, 15, 16], Nimb et al. [17], Pedersen et al. [18], Müller-Spitzer et al. [19, 20] and many others. The term "dictionary" was first coined in Medieval Latin in the 13th century on the basis of Latin derivative 'diction' (word). Dictionary is viewed as a lexicographic edition arranged in some stated order that deals with the individual words of a language and provides their orthography, pronunciation, grammatical characteristics, derivation and history [21]. It is a systematically arranged list of socialized linguistic forms derived from the speech-habits of a certain speech community accompanied by the author's remarks on their usage and aimed at the readers' better understanding. Dictionary has various practical purposes. It is a useful reference book, a 'store house' for a language; a detailed guidebook for distinguishing good usages of lexical items from bad usages, a 'court house' for a language [22]. It is the source of linguistic and extralinguistic information which is authentic and reliable.

Burada and Sinu [23], Kwary [24], Weschler and Pitts [25], Winkler [26] have recognized the advantages electronic lexicographic editions. Electronic dictionary (digital dictionary is a generic term for various types of electronic lexicographic editions and is viewed as any reference material presented in electronic form providing information about the lexical units' spelling, meaning, pronunciation and use [14]. Such a dictionary is a computer database of the specifically coded entries to enable quick word search with regard to morphological form and with the possibility of searching word combinations and changing translation direction [27]. It is a new structured text including data represented in different media such as audio files, videos, graph-based views etc. that has a definite volume, a clear aim and serves a specific idea. Therefore, an electronic dictionary is networked, linked to a device, and people-oriented.

Several studies suggest electronic dictionaries characteristic features, namely [27, 28]:

- a peculiar combination of text and hypertext form of lexical material representation;
- verbal as well as non-verbal means of lexical unit description availability;
- sufficient search facilities within dictionary wordlist as well as in various Internet sources.

There have been numerous studies to investigate electronic dictionaries form and function. Thus, all electronic dictionaries are classified according to [27, 29, 30]:

- a dictionary user (a human or a machine);
- languages involved: monolingual, bilingual and multilingual dictionaries;
- form: online (located in the Internet) and electronic (distributed on CD) dictionaries;
- information arrangement: textual and hypertextual (among which one can distinguish between creolized (with extralinguistic elements such as pictures, audio and video) and non-creolized dictionaries);
- operational system and loading mode parameters: dictionaries designed for MS DOS and dictionaries designed for Windows, non-residential (with their own shell program) and residential (called from other applications);
- word list arrangement: frequency-ordered, alphabetically ordered, thesauruses, thematically grouped, concordances, special purpose dictionaries, combined dictionaries etc.;
- information medium and devices: computer (set up on the desktop computers), pocket (recorder in pocket electronic devices), mobile (used in smartphones), stationary (installed on computer hard disc), portable (distributed on CDs), online (available in the Internet) dictionaries;
- language varieties: normative, literary language, regional dialect, social-group dialect dictionaries and others.

Studies of dictionary structure are well documented [27, 31, 32]. Prior research proves that electronic dictionary has a well-developed architecture that contributes to quick word search. It consists of macrostructure and microstructure. The macrostructure is viewed as the organization of the lexical entries in the body of a dictionary [33] and comes in two types – semasiological and onomasiological. It includes introduction that goes before the body of a dictionary, tables and appendices (supplements) [34]. The microstructure is the organization of lexical information within lexical dictionary entries. It outlines the linguistic unit properties in terms of its content (pragmatics and semantics), structure (syntax and morphology) and rendering (form).

In recent years, research on electronic dictionary compilation has become very popular among linguists (e.g., Bergenholtz and Bothma [35], Rehm et al. [36], Wright et al. [37], Wright and Cervetti [38]). There exists a considerable body of literature on lexicographical modeling [39, 40], linguistic and machine methods for dictionary compilation [41], computational approach to lexicography [42, 43], text parsing programs for online dictionaries [44], dictionary writing systems [45] etc.

Due to constant scientific developments and improvements, significant changes that occur in modern lingual environment are primarily related to terminology. Therefore, terminological units' presentation in electronic dictionaries is in the focus of scientific study by Andrianova and Makarova [46], Sperberg-McQueen and Burnard [47].

The *aim* of our study is to investigate the algorithm of electronic multilingual terminological dictionary (EMTD) compilation. EMTD is viewed as a dynamic electronic dictionary that is open to current trends in its fields of knowledge representation. It is absolutely adapted to constant updating, extension and integration with other systems needed. Moreover, it is rather flexible as for quantitative and qualitative terms. EMTD does not only outline the definition of terms, but also provides English, French, German, Polish and Russian equivalents with encyclopedic reference in the target language. EMTD has a lot of advantages as it aims at providing detailed encyclopedic information which is absolutely necessary for adequate translation. Moreover, it gives illustrative examples that greatly highlight the distinctive features of a terminological unit and shows its usage in different contexts.

3. Results

Electronic dictionary compilation is a meticulous process which takes time and efforts. To compile a quality electronic lexicographic edition all regulations and requirements should be decently followed. In short, the literature pertaining to the peculiarities on dictionary compilation strongly suggests that it is a multifaceted process that includes the following stages [48]:

- structural, semantic, functional and socio-cultural understanding of language(s);
- structuring and ordering entry information;
- compiling the lexical database;
- checking and refining lexical database information;
- manipulating the data for analytic or other purposes;
- output which presupposes deciding on the format and making the necessary adjustments;
- printing (for printed dictionaries);
- marketing and distribution.

The analysis of existing approaches to electronic dictionaries compilation has driven the further development of the algorithm of EMTD compilation (figure 1).

EMTD compilation undergoes several stages aimed at improving its quality and satisfying the dictionary users' needs. It starts with the creation of the register in the target languages – Ukrainian, Russian, Polish, French and German. As soon as the register is ready, it is sufficiently checked and arranged according to the requirements of terminology codification and unification.
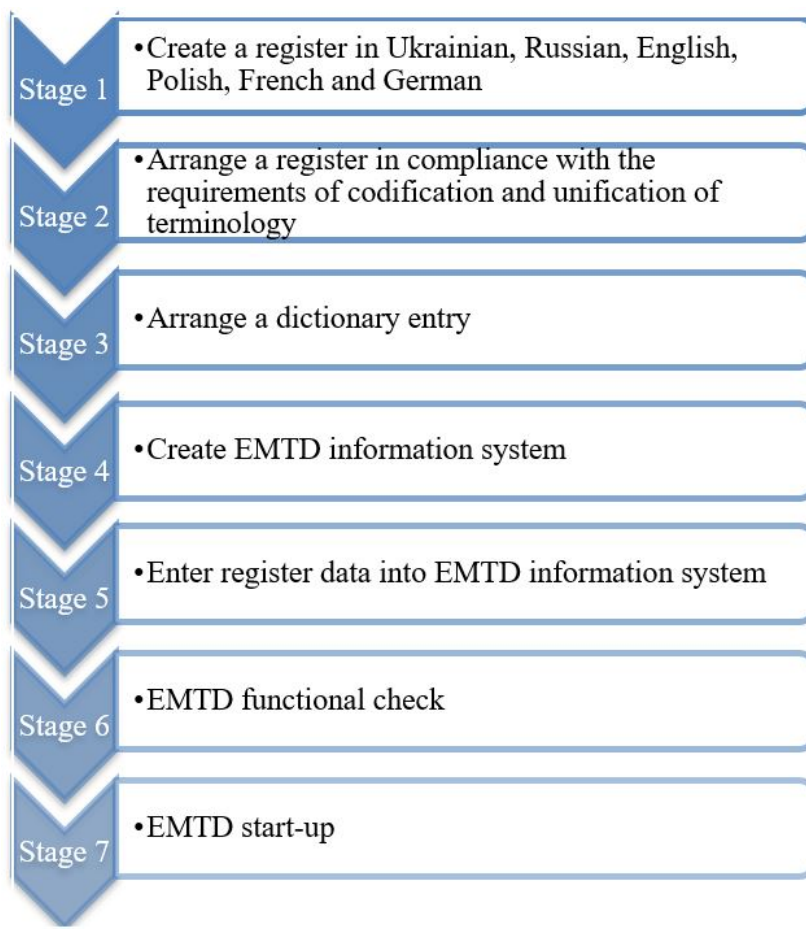
Figure 1: The algorithm of electronic multilingual terminological dictionary compilation.

The next step is dedicated to EMTD entry structure that presupposes thorough macro and microstructure arrangement. Then EMTD information system is created and register data is entered. After that EMTD should undergo a thorough functional check. Last but not least is EMTD start-up.

Moreover, EMTD creation presupposes comparative and contrastive studies that are based on general principles of terminology analysis. The following principles include comparability, consistency, and sequence of linguistic data analysis [40]. Comparative analysis is conducted at the level of subsystems, fields and groups, whereas contrastive analysis is done at the level of a definite terminological unit from one language to its possible equivalence in the languages given.

For the current research, it is sufficient to point out the peculiarities of the stages mentioned above.

3.1. Creating a register

As it has been previously reported, the basis of any dictionary lies in its register. Each word of the register has its own EMTD entry with peculiar structure. A terminological unit is the main structural component of the entry that highlights its grammatical parameters, phonetic and morphological peculiarities as well as synonymic variants if any [49].

It should be noted that for terminological units' selection we use only authentic texts that meet the following requirements:

- authentic language (written in the author's mother tongue);
- sufficient academic degree of the author (Doctor of Philosophy (PhD), Associate Professor, Professor);
- issue date (less than 10 years).

To create the register the main academic principle of terminological units' selection should be implied. The principle presupposes conducting linguistic and statistical analysis of lexical units from selected sources. The analysis starts with ranking of the terminological units to the frequency of their usage. If a term is widely used the compilers include it in the register.

Each EMTD section is dedicated to a certain area of knowledge and consists of 300 entries. Therefore, a careful and thorough terminological units' minimum selection is a significant prerequisite for efficient EMTD. A well-organized and sufficiently selected register is necessary for the expression of an idea or concept. Therefore, decent register creation greatly depends on mutual efforts and effective cooperation of linguists and specialists in the corresponding subject areas.

3.2. Arranging a register

Arranging the register special features of terminological units should be considered. Therefore, contrastive and systemic analysis should be implied. Contrastive description of the lexical units' meanings from various semantic categories and different languages has a paramount value. It helps to avoid unwanted terminological confusion and significantly contributes to the users' better understanding of a certain phenomenon. Systemic analysis is done both at the level of comparable subsystems and parallel pairs of terms. It aims at coordination and harmonization of terminological units. Peculiar attention is given to avoid terminological confusion as presence of several terminological units' translations and lack of their thorough distinguishing features as well as erroneous translation equivalents lead to distortion of a term and cause misunderstanding. Thus, terminological system modeling requires the use of comparable logical-conceptual schemes.

3.3. Arranging the dictionary entry

Recent theoretical developments have revealed that EMTD compilation should be done in accordance with the following requirements [50]:

- thorough and sufficient vocabulary coverage of the subject areas;
- availability of the necessary information about the terminological units;

- avoidance of redundant information that increases the dictionary volume, prevents easy word search and consequently causes misunderstanding;
- unification of the dictionary structure and apparatus of links to facilitate the users' search;
- coherence between the dictionary structural components.

Therefore, EMTD entry is of primary importance as it is one of the main EMTD structural components. EMTD entries are viewed as sets of information about terminological units and classified into thematic areas: Information Technologies; Linguistics; Engineering; Accounting and Taxation; and Economics. EMTD entry arrangement should significantly contribute to thorough systematization of terminological unit knowledge on all levels – phonetic, morphological and semantic, therefore it comprises the following parts:

- definition which is one of the most significant constituents of a EMTD entry that provides explanation of terminological units meaning. It serves to resolve the communicative EMTD users needs of decoding and encoding [31]. Definition should include only relevant information to meet the expectations of the target users and comply with the general principles [51]. It should avoid circularity therefore contributing to better understanding of a terminological unit meaning. Moreover, it should define every word used in a definition not to prevent the user from full understanding. Definition should explain but not just talk about the word and its usage, thus being enough informative
- pronunciation contributes to the correct way of uttering terminological units;
- grammatical information indicates a part of speech, differentiates between transitive and intransitive verbs, countable and uncountable nouns etc.;
- labels are viewed as orientation marks of the region, field or any other specifications according to which the use of a terminological unit can be limited. Labels fall into three types: status, regional and subject. Among them register, style, time and attitude may be as well distinguished [31];
- semantic relations particularly refer to synonyms, antonyms, collocations, cases of hyponymy or hypernymy [52].
- phraseology includes phrasal verbs, idioms and collocations which are usually stated at the end of the entry. It may be marked with signs referring to limitations in a word use and followed by relevant examples;
- etymology highlights the origin of a word and its development during the time. It significantly contributes to better understanding of the current meaning and thus enhances the general knowledge of it;
- providing examples is a negotiable issue and depends on the users' expectations. Although, examples should be natural and typical, thus present a term in the most frequent contexts, syntactic patterns, collocations and multiword expressions keeping the balance between too much context and too little [31]. Moreover, examples should be informative implying only relevant information not dispersing the users' attention. Last but not least refers to intelligibility which is gained by avoiding sophisticated lexis and structures wherever possible [31].

Most early studies as well as current work focus on the importance of a thorough terminological unit definition. Undoubtedly, a good definition facilitates EMTD users' understanding

and greatly contributes to their professional competence development. Accordingly, it should have the following features [53]:

- have no logical contradictions. The definition should be transparent in meaning. It should not imply difficult terms for rendering the notion;
- be clear and precise;
- have positive predicate;
- be neither overdefined nor underdefined;
- be defined in the simplest possible language.

Furthermore, to meet EMTD users' requirements the compilers make the lexicon easily searchable considering the following features [54]:

- headword lookup should be in accordance with printed dictionaries primary macrostructure thus enabling EMTD users to access EMTD entries by simply searching for headwords matching a string they type in;
- part-of-speech indices that help EMTD users to search for entries of a certain subcategory of a part of speech;
- etymology or morphological composition indices;
- register indices that imply reference to literary, slang, professionalisms and other words;
- semantic field indices to provide EMTD users with a hyperlink to a list of all other terms belonging to a particular area of knowledge;
- phonological content of headwords to contribute to EMTD users' correct pronunciation.

EMTD should become a sufficient tool in helping EMTD users to enhance understanding in their readings. Hence, EMTD offers the opportunity of quick six-language A/Z search that makes the search process rather user-friendly and less time-consuming.

3.4. Creating EMTD information system

Creating EMTD information system requires much time and consideration. The primary concern goes to laying out the database and data flow to the sort of terminological units' visual presentation on the page. Undoubtedly, the era of designing electronic dictionaries in the same way as paper dictionaries has already gone [55]. Therefore, EMTD should be architected in order to satisfy its users' needs. Every EMTD feature has to be thoroughly planned to make the users' benefit from the dictionary layout.

EMTD has minimal constraints on adding new features or implying more languages. It has two-level expandability, namely: depth (new terminological items may be added to each language); width (new languages may be added). Consequently, EMTD could be further developed and enriched which is significantly important due to constant scientific and technological progress. Thus, we have no technical obstacles to further develop the project on EMTD compilation.

Moreover, EMTD enables smooth data manipulation. It is hosted on university servers that make all the documentation, codebase and language database securely backed up. Furthermore, to satisfy EMTD users' needs, three device types are proposed: computers, tablets and mobile

phones. Therefore, the compilers have to ensure optimal accessibility of data on display to EMTD users. Accordingly, responsive design-driven methodology to scale EMTD design down to resolution of 480x960 pixels retaining all the features of the page is implied.

3.5. Entering register data into EMTD information system

As soon as EMTD information system is created and the register is done in compliance with the requirements of terminology codification and unification, entering register data stage begins. The following stage is rather time-consuming and requires significant efforts. Nonetheless, thorough and meticulous approach used significantly facilitates the process.

3.6. EMTD functional feedback

EMTD quality greatly depends on active implementation of EMTD users' needs. Therefore, to corroborate the necessary data several research instruments are used. Open-ended questionnaires, focus group interviews, and email responses are rather helpful in getting EMTD users feedback. A sound idea lies in an urgency to obtain the feedback from the target users while dictionary compilation is still in progress [29]. Thus, the dictionary-making process is strictly guided in order to satisfy all target users' needs.

What is more, EMTD evaluation is carried out by linguists and specialists in the corresponding areas of knowledge. The specialists take into consideration its suitability and applicability to the curriculum as well as test its features, for instance:

- accuracy;
- multi aspect educational value;
- up-to-date educational standards;
- sufficient language wording;
- complete data;
- ability to encourage and motivate the users' interest;
- ability to improve the users' professional skills.

The following features guarantee the quality of EMTD and its applicability in the educational process. Moreover, EMTD is tested for its reliability, interactivity, controllability, menu, search and control methods, appropriate font, consistent screen layout, technical errors etc.

3.7. EMTD start-up

Right after EMTD information system is checked, it is given wide public access. It is worth noting that EMTD start-up is not the final stage. This stage presupposes numerous testing of EMTD functions, which is of paramount importance for further EMTD improvement and, accordingly, support.

4. Conclusions

The rapid scientific and technological development in various domains of knowledge requires lexicographical modeling of electronic multilingual terminological dictionaries (EMTDs) that are among the most useful and comprehensive terminographic resources. An EMTD is a special electronic lexicographic resource that provides translation, explanation, and encyclopedic information for terms in five thematic areas: Information Technologies, Linguistics, Accounting and Taxation, Engineering, and Economics. It presents information about terminological units at phonetic, morphological, and semantic levels. An EMTD also features a fast and user-friendly six-language A/Z search function. The paper proposes a systematic algorithm for compiling an EMTD that consists of seven interrelated stages: creating and organizing term registers, developing and testing an information system, and setting up the dictionary. The paper discusses the criteria and methods for determining the volume and structure of the EMTD, selecting and ranking the terms, and providing translation equivalents and encyclopedic references in all target languages. The paper demonstrates how the proposed algorithm can facilitate the production of a high-quality EMTD that meets the needs of its users. Future research is needed to validate and generalize the findings of this study. Moreover, investigating the EMTD model might reveal new insights and challenges.

Acknowledgments

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